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# RADIO FREQUENCIES AND MICROWAVES. MAGNETIC AND ELECTRICAL FIELDS

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ABBREVIATIONS

EMF — electro-magnetic field
UHF — ultrahigh frequency
SHF — superhigh frequency
HF — highfrequency
SW — short wave
USW — ultra short wave
MCW — microwaves
PPM — power current density
PE — energy density
CNS — central nervous system
RLS — radar station
MPL — maximum permissible level
PNS — peripheral nervous system
LFI — low-frequency intensity
ENT — ear, nose, throat
EF — electrical field
SEF — static electric field
GMF — geo-magnetic field
MF — magnetic field
emf — electro-magnetic force
SEF — static electric field
ATF — adenosine triphosphate
LFP — low-frequency pulse
ROE — sedimentation rate
MW — medium wave
PMF — permanent magnetic field
VMF — variable magnetic field
ADP — adenosine diphosphate

# I. GENERAL IDEAS ON THE OCCURRENCE, SOURCES AND MECHANISMS OF ELECTROMAGNETIC RADIATION, ELECTRIC AND MAGNETIC FIELDS

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## 1. Physical Characteristics of Natural and Artificial Electromagnetic Fields (EMF) in the Biosphere

A common characteristic of EMF in all ranges — from geomagnetic and /3* geoelectric fields of the Earth to solar radio emission — is the periodicity of their intensity changes: daily, monthly and seasonal. A second common characteristic of the Earth's electrical field and of the atmospheric and radio-emission fields is their approximately identical minimum average intensity in the environments of organisms, on the order of $10^{-5}$ V/m (for radio emission in the atmosphere, for atmospherics and for the electric field in a water medium). Along with periodic changes around this average value, spontaneous changes also occur (increase in intensity) in the EMF of the biosphere which vary from doubling their average level to exceeding it hundreds of times (radio emission). Spontaneous changes in the EMF of the biosphere are related as a rule to corresponding spontaneous changes in solar activity, during which

*Numbers in the margin indicate pagination in the original foreign text.

simultaneous changes occur — magnetic crochet,* intensification of low-frequency atmospherics, outbursts of solar radio emission, as well as delayed (20-40 hrs) changes — magnetic storms, aurora polaris.

The average EMF intensities and the character of their daily periodicity vary in different geographic latitudes. The electrical field is at a maximum in the middle latitudes, and decreases toward the poles. Daily changes in this field over ocean polar regions occur at a single universal time, and over the remaining regions of dry land daily changes occur in local time. The horizontal component of the magnetic field decreases, but the vertical component increases from equatorial to polar latitudes; daily variations in the geomagnetic field at equatorial latitudes differ from middle-latitudes in their greater amplitude and contrasting phase. The intensity of atmospherics (storm activity) is at a maximum at equatorial latitudes and decreases toward polar latitudes. Daily changes occur simultaneously all over the Earth, as well as in local time — with maximum amplitude during the night hours. /4

With increasing distance from the surface of the Earth, the electric field decreases approximately exponentially (average intensity at the surface is 130 V/m, and at an altitude of 50 km it is 0.1 V/m). The magnetic field decreases in approximately inverse proportion to the cube of the distance from the center of the Earth. Atmospheric discharges, occurring through the ionosphere (from 80 to 1000 km) and the exosphere (beyond 1000 km) are perceived as variable frequency noise — "whistling atmospherics" — in a range of approximately 1-20 kc. In this range EMF are directly produced in the exosphere — UHF radiation.

Artificial EMF are formed in the biosphere because of the emission from radio and television stations which create a unique "radio background" around the Earth. It is thought that the average level of intensity of the radio background is approximately 10-100 times higher than the average level of intensity of the atmospherics of corresponding ranges.

*Translator's Note: This is a sudden change in the Earth's magnetic field due to increased conductivity of the lower ionosphere.

In this case, in areas around radio and television stations it can be very strong — on the order of tens of V/m. /5

As all stations radiate incoherently, the "radio background" is then the result of accumulated radiation. In the environs of long-wave and medium-wave stations, as well as television stations, there is daily periodicity of intensity variations, as these stations usually discontinue operations from approximately 1 a.m. to 6 a.m. Short-wave stations, transmitting all over the world, operate practically around the clock.

Local artificial EMF zones are created around generators and affect only the staff directly attending these generators in industrial plants, radio, and television stations and medical institutions. According to the evaluations of Soviet hygienists, EMF intensities at working sites are:

a) EMF (50 cps): in electrotransmission lines, transformers, etc., field intensities can reach hundreds of V/m, and in open distributors they can reach thousands of V/m.

b) High-frequency EMF (hundreds of kc): intensities close to the generators (for hardening metals, drying wood pulp, etc.) can reach thousands of V/m and dozens of A/m with respect to the magnetic component.

c) Ultra-high frequency EMF (from several to tens of Mc): intensities reach hundreds of V/m.

d) Superhigh frequency EMF (from hundreds to thousands of Mc): can reach several $mW/cm^2$ in terms of flux density. /6

In the USSR, maximum permissible intensities of EMF [1] have been established for the 100-3000 kc range : 20 V/m and 5 A/m
for the 3-30 Mc range : 20 V/m and 5 A/m
for the 30-300 Mc range : 20 V/m and 5 A/m
for the 300-300,000 Mc range 10 $\mu W/cm^2$

## 2. Possible Mechanisms of the Informational Effect of EMF on Organisms

The extreme sensitivity of biological objects to EMF cannot be explained by the energy interaction between very low quanta and molecules of biological substances, but is due to the existence of biosystems which are able to receive information carried by very low-intensity EMF. There is a basis for assuming that such high sensitivity results from the ability of corresponding biosystems to accumulate space and time information. By these methods the reception of the total ratio $R_{signal}/R_{noise}$ increases $\sqrt{n}$ times ($n$ — the number of elementary receivers or the number of recurrent signals). At sufficiently large $n$, it is possible to receive information even if the energy of the signal << kT, i.e., reception by biosystems of information carried by very weak biosphere EMF. In disturbances of biological control, with spontaneous changes in the biosphere EMF, or under the effect of artificially /7
created EMF in experiments, we evidently encounter the direct "interfering" effect of EMF on electromagnetic interrelations in the organism itself. As has now been established, these relations play an important role in directing processes at all levels of biological organization.

At present, sufficient data are lacking to explain specific mechanisms of these adequate and inadequate reactions of the organism to external EMF. However, certain considerations can be cited in this connection on the basis of modern concepts of general, functional regularities of biological regulation and its interrelationship with the external medium [28-30].

As has now been established, at all levels of biological organization, regulation of processes and its dependence on external effects are due to the activity of two interrelated controlling systems — "slow" and "fast acting". The first stabilizes the function of a given biosystem in a wide class of external influences, reacting only to systematically recurring effects and accordingly adjusting (over a prolonged latent period) changes in the internal

medium, causing active reorganization of the biosystem function, in conformity with the systematic influences. The second reacts quickly to any random external influences, protecting the slow system from them and informing that system of those influences.

Experimental studies of various manifestations of biological regulation /8 show that, firstly, there is a complete hierarchy of these systems in the organism, interrelated with each other by the principle of unification and subordination; secondly, EMF with low-energy quanta play an important role in information interactions within these systems and between them. Thirdly, the central-slow systems are "narrow-banded" in relation to the parameters of external EMF (in frequency, amplitude, character of modulation), i.e., they are by evolution adapted to receiving information carried by biosphere EMF with definite, regularly changing parameters, and the peripheral-quick acting systems are "wide-banded" — they react to any, adequate or inadequate, EMF of the external medium.

According to modern experimental data and theoretical considerations, the various processes in a living organism occur in a fluctuating regime. The regulation of these processes — their coordination in time between themselves and with the periodic changes in the external medium, is accomplished by synchronization of fluctuations and their modulation with internal and external periodic influences. The hierarchy of the fluctuating processes of this type in organisms has already been discovered — from molecules to the organism as a whole. Most interesting are conformation fluctuations of biological elements and systems which represent inverse cyclic changes of volume and form. A characteristic feature of these fluctuations is, firstly, that they are "quasi-isoenergetic," i.e., cyclic changes in form and volume are related to absorption and release of extremely small quanta of energy

( $h\nu \ll kT$). Secondly, these fluctuations are always connected with /9 electromagnetic ones — they are fluctuations of orientation of the electric and magnetic moments of macromolecules, the distribution of their surface

electric charge, and the ratio of surface polar and nonpolar groups. They are fluctuations in the distribution of surface charge in organelles and cells, changes in their membrane potential, variations in their constant dipole moment; they are fluctuations in the distribution of electric potentials on the surface of the body of animals.

In recent years direct experimental data have been obtained about the existence of extremely large constant dipole moments [31-33] in protein molecules hundreds of times larger than in molecules of water, in viruses — tens of thousands, in colloid micelles — hundreds of thousands, and in cells — millions of times larger. The ability of plant and animal cells to be magnetized and magnetized in reverse in a comparatively weak magnetic field [34-36] has been discovered; the formation of a magnetic dipole has also been discovered in insects [37]. Finally, the formation of low-frequency EMF around various biological objects has been discovered [38-40] — the nerve of a frog, the isolated heart of a frog, in the vicinity of insect bodies, in the vicinity of a human body. These fields were recorded even at quite large distances from the object — to tens of centimeters.

To approach an explanation of the mechanisms of biosystem reactions to adequate and inadequate influences of EMF in the external medium, the following methods have thus already been noted: /10

a) Modulation of synchronized fluctuations at various levels of biological organization with periodically changing (for example, daily) fields of the biosphere

b) Orientation reactions of biosystems as a result of the influence of geomagnetic and geoelectric fields on dipole electric and magnetic properties of groups of macromolecules and cells

c) Disturbance of biological regulation under the influence of external medium EMF inadequate for the organism, because of the effect of these fields

on electromagnetic information interrelations in the organism, especially in the organism's developmental period and during pathological conditions.

The basic difficulty in considering the mechanism of the generation and development of EMF in living organisms is the fact [29] that electromagnetic fluctuations in biosystems cannot be described in the language of "classical" fluctuation theory. Thus, for example, the extremely low quality of a biosystem, considered as a resonator, despite the theory of fluctuations does not prevent the development of fluctuations in it.

### 3. Possible Damage to the Regulatory Function of the Organism in Outer Space

The problem of the effect of EMF on plants, animals and man during space /11
flights and while on the Moon and on the planets in our system includes three basic questions: how will the absence of terrestrial EMF affect the vital activity of organisms at great distances from the Earth? What effect will the EMF existing in outer space and on other planets have on organisms? What will be the effect of the prolonged influence of EMF, created by instruments and apparatus, on organisms in spacecraft?

There is a basis for assuming that the absence of biosphere EMF in space should somehow affect the biological rhythms of organisms, and affect their ability to orient themselves in space and time [41]. As has already been mentioned, in the case of significant compensation of the effect of natural EMF on organisms, disturbances have been observed in the biological rhythms of exchange and reproduction in plants and animals, disturbance of rhythms of physiological processes and in the ability of man to orient himself in space and time. Disturbances of the mental functions of man are also important in compensating for natural EMF, although studies have only just begun in this respect.

The necessity is obvious of making serious studies of the behavior of animal organisms, deprived of the continuous effect of biosphere EMF. It is most necessary to find out: how long the human organism can function normally under these conditions because of his various adaptive mechanisms (if such mechanisms exist at all in relation to a change in EMF).

Further, the question must be answered of whether man can become adapted /12 to these conditions by appropriate conditioning or by the prophylactic effect on the organism of certain chemical and physical factors? It must be emphasized that these questions can only be answered through prolonged tests under conditions where there is no terrestrial EMF. The effect of weightlessness on an organism, already having been studied for quite some time, has only been determined for comparatively short periods of time.

Concerning plant organisms — chlorella, for example — we can hardly consider preserving their vital activity rhythms under conditions where the effect of all periodically-changing geophysical factors, including electromagnetism, is completely absent. It will possibly be necessary to simulate in the spacecraft these periodic factors, among which electromagnetism plays an essential role. Perhaps this simulated biosphere EMF will also be necessary for the normal functioning of the human organism.

In hygienic research on the unfavorable effects of EMF from low to superhigh frequencies, as well as the effect of constant electric and magnetic fields, a great deal of experience in protecting people from those effects has been accumulated. This is attained by screening the EMF generators themselves, by using different kinds of coverings to absorb EMF, and finally, by using individual protectors — special suits. All these protective means can be used in relation to EMF, artificially created by the craft's instru- /13 ments. However, in this case the most important problem is also the <u>duration</u> of the effect of these fields. In hygienic research, the unfavorable effect of EMF is discovered in their extremely prolonged effect — for months and even years. Is protection from these effects necessary during space flights?

On the other hand, unfavorable effects of EMF under industrial and operational conditions were studied when the people were under normal conditions in all other respects. But in space conditions we are dealing with a combination of the most varied unusual situations. Are not more strict criteria necessary here in relation to the unfavorable effect of artificially created EMF?

In regard to the effect of EMF of space origin, we still know very little about their parameters. A priori it can be assumed that, if EMF do not greatly differ from the artificial "radio background" existing on Earth (whose intensity as we mentioned is 10-100 times greater than a natural background), then we need not consider their effect. We cannot detect any clear effect of the "radio background" on living organisms (although this does not mean there is no effect of any kind). However, in this case it is also necessary to keep in mind that the remaining environmental conditions in space flights differ from Earth, and, consequently, appropriate corrections must be made in evaluating the possible effects of cosmic EMF.

## II. CLINICAL-PHYSIOLOGICAL DATA ON THE BIOLOGICAL EFFECT OF RADIO FREQUENCY EMF AND THE HYGIENE OF WORK /14

Soviet studies in recent decades have made significant steps forward. From an analysis of individual aspects of biological activity, from particular questions of the hygiene of working with sources of radio wave radiation, we have proceeded to an integral analysis of changes at various biological levels, and to improving hygienic studies. They include discrete sections of all ranges of radio waves, which are important in various branches of industry, science, technology, and culture. The researchers are interested in the production processes from the moment when the first model is created of a transmitter, of radar station units, of a radar complex, of high-frequency generators widely used in radio communications, the heat treatment of metals and insulators, etc., to their mass production, operation, and finally, repair.

## 1. Hygienic Studies and Standardization

For a hygienic evaluation of working conditions in relation to the range of frequencies, the parameters of radiation sources, the technological process and the work regime, the following basic processes are distinguished: [Gordon, Z. V., 1958], having varying importance in the national economy: /15

I — development and mass production of radiation sources;
II — operation of finished radiation sources;
III — repair of equipment.

Depending on the wavelength range and the technological process, certain processes are of predominant importance.

Works with SHF sources have attained the widest importance. For this range of frequencies, six groups of operations are distinguished [Z. V. Gordon, 1966] which can be ordered as follows according to their hygienic significance:

Group 1 — control, adjustment and testing of a radar station complex (RLS) in factory and repair shops;

Group 2 — control, adjustment and testing of an RLS complex under working conditions;

Group 3 — control, adjustment and testing of individual SHF units and instruments;

Group 4 — work conditions connected with the presence of SHF energy sources in scientific-research institutes;

Group 5 — work conditions connected with RLS operation, in particular in civilian establishments;

Group 6 — work conditions with SHF-apparatus in certain branches of the national economy, for example: aerological stations, radio-relay communication lines, physiotherapy rooms and every-day instruments — ovens for food preparation. /16

For UHF and HF ranges, the most important from a hygienic point of view, are the processes in operating UHF and HF instruments, radio communication, broadcasting, television, heat treatment of metals and insulators, etc.

Depending on intensity and duration of the effect, it is practical to represent three groups of operations connected with irradiation [Z. V. Gordon, 1958, 1966]:

— First group — periodic effect of high-intensity radiation;

— Second group — periodic effect of low-intensity radiation;

— Third group — systematic effect of low-intensity radiation.

For the whole range of radio frequencies, there are approved health standards and common health rules.

Comprehensive studies of the conditions of working with electromagnetic wave radiation sources in the radio-frequency ranges have led to recommendations of standard protective methods [Z. V. Gordon, A. S. Presman, 1956, A. S. Presman, 1958, B. M. Belitskiy, K. G. Knorre, 1960, Z. V. Gordon, V. V. Yeliseyev, 1964, P. P. Fukalova, 1964]. /17

A special section is devoted to hygiene studies in the operation of radio transmitters in the air, sea and river forces [T. V. Kalyada, V. N. Nikitina, 1968; Ye. L. Kulikovskaya, 1968; A. Ya. Loshak, V. L. Gilinskiy, 1968]. It has been shown conclusively that correct positioning of radar /18

TABLE 1. SAFE RADIATION INTENSITIES FOR VARIOUS RADIO-WAVE RANGES:

| Wave ranges | Frequency ranges | Safe radiation intensities |
|---|---|---|
| Medium waves [MW] | 60 kc - 3 Mc | 20 V/m intensity of the electric field<br>5 A/m intensity of the magnetic field |
| Short waves [SW] | 3-30 Mc | 20 V/m |
| Ultrashort waves [USW] | 30-300 Mc | 5 V/m |
| Microwaves [MCW] | 300-300,000 Mc | 10 $\mu W/cm^2$ - working day<br>10-1000 $\mu W/cm^2$ - to 2 hours a day<br>100-1000 $\mu W/cm^2$ - 15-20 min. a day |

antennae — for example, at airfields and on various kinds of ships — provides "dead space" on the decks and superstructures and at airfields.

In recent years special attention has been given to SW and USW ranges, used in radio communications, radio transmission, and television.

It can be satisfactorily stated that new transmitter systems, especially for television, which have been constructed with consideration for health standards, undoubtedly have an advantage from a health point of view over old systems.

Thus, in television stations under construction and in those being remodeled, completely adequate working conditions are being created.

One of the most modern methods of organizing multichannel intercity telegraph-telephone communications and of transmitting television programs over large distances is the use of radio-relay communication lines. Evaluating the radiation intensity received by receiver-transmitter operators from a health point of view has made it possible to verify the fact that operators, as a rule, are not subjected to radiation with intensities exceeding safe limits [Z. V. Gordon, N. D. Khramova, 1968].

It is very important to study working conditions in new and still unstudied areas of the national economy where radio-frequency FMF sources are used. These include plasma equipment for diagnosing plasma, accelerators, where — because of the character of the technological process — radio-frequency radiation, x-rays and a permanent magnetic field can have an effect. /19

The study of x-rays from SHF equipment is of particular importance. These studies preceded a very difficult period of creating an x-ray dosimeter with the simultaneous presence of SHF radiation. But this problem has also been solved, and the dosimeter proposed now can objectively evaluate the intensity of x-rays on SHF instruments (modulator and generator units, etc.).

The first data on the fact that SHF equipment could generate x-rays during operation appeared in the Soviet literature at the end of the 50's.

Changes in the health of workers were revealed by R. N. Vol'fovskaya, Yu. A. Osipov, T. V. Kalyada, et al. (1961), Yu. A. Osipov, R. N. Vol'fovskaya, T. P. Asanova, et al. (1963), A. V. Shcheglova (1962) in examining women who vacuumized and tested certain types of electron tubes in the electro-vacuum industry. During the work process, they were subjected to the combined effect of HF electromagnetic fields (200-250 kc) and medium strength x-rays (80-100 kV). /20

Until recently there were serious problems in relation to the dosimetry of x-rays in work areas. Difficulties in measuring develop because of the simultaneous presence of electromagnetic SHF fields, picked up in the instrument, as well as from the pulse character of the radiation.

As x-rays in SHF equipment generate very short pulses, neither radiometers with counter tubes, nor instruments in which the radiation detectors are ionization chambers are suitable for recording the high instantaneous values of radiation intensity.

At the present time, measuring is done by using various instruments based both on ionization and on scintillation principles.

In the works of K. V. Nikonova, N. D. Khramova (1968), K. V. Nikonova, N. D. Khramova, N. V. Kartashov (1968) information is presented about the intensity of soft x-rays and SHF radiation in the radio engineering and electronic industries.

The authors pointed out that the intensity of x-rays depends on the type and working regime of the instrument and on the presence of protective screens. Thus, the strongest radiation sources are modulator tubes operating at high anode intensity and powerful klystrons. Maximum radiated power in the working area, according to the data of K. V. Nikonova, N. D. Khramova, /21
N. V. Kartashov (1968), is tens of microroentgens/second.

In recent years definite results have thus also been attained in the hygiene plane. And in the future, in proportion to the development of radio technology and radio electronics, hygiene problems during work will be the center of attention.

## 2. Clinical-Physiological Observations

Data of recent years, supported by electro-physical, biochemical and special research, have widened our knowledge in the field of occupational

pathology and with still greater conclusiveness indicate the cumulative biological effect under the prolonged influence of low-intensity radiation.

This extremely important fact of a cumulative biological effect is expressed in the constantly increasing damage to the nervous system, especially in its vegetative sections, as well as in cardio-vascular, neurohumoral changes.

The effect of radio-frequency electromagnetic fields on nerve regulation of the cardio-vascular system was observed by a number of authors in the clinical examination of individuals subjected to the chronic effect of radio waves. The research of A. A. Orlova (1960), M. N. Sadchikova (1964), N. M. Konchalovskaya, et al. (1964) shows that the chronic effect of fields of various ranges of athermal intensity decreases the blood pressure level, heart contraction rhythm and slows intraventricle conductance. However, the most pronounced are those changes under the effect of the SHF-range (Table 2), according to the data of N. N. Sadchikova (1964).

These changes are characteristic of vagotonic changes in vegetative nervous regulation. In prolonged work under unfavorable conditions, there are significant increases in the asthenic affect of radio frequencies, vascular-vegetative changes become very persistent, and can also be revealed in vascular-vegetative dystonia with vascular paroxysms, resulting from neurocirculatory disturbances. /22 /23

Thus, in proportion to the increase of changes, a certain stage a neurocirculatory interval develops with signs of diencephalic insufficiency. This is indicated by: a clinical pattern shown in the paroxysmal state in the form of periodically occurring vascular crises with severe fluctuations in blood pressure; by anomalies in the electrical background activity of the brain.

Shifts in the functional condition of the diencephalic region are indicated by changes in the constant and induced activity of the retina;

TABLE 2.

| EMF parameters<br>Frequency Range | Intensity of radiation | Ratio of % of cases with damage to % in control | | |
|---|---|---|---|---|
| | | Lowered blood pressure level | Slowed heart-beat | QRS interval extended to 0.1 sec. in ekg |
| SHF(centimeters) | from one to several $mW/cm^2$ | 1.85 | 24 | 11.5 |
| UHF | to 1 $mW/cm^2$ | 2.0 | 16 | 12.5 |
| HF | | 1.2 | 8 | 21 |
| short waves | tens-hundreds of V/m | 0.21 | 12 | -- |
| medium waves | from hundreds to 1000 V/m | 1.2 | 5 | -- |
| Percent of cases in the control group | | 14% | 3% | 2% |

(constant potential and electroretinogram of N. N. Goncharova, V. V. Karamyshev, et al., 1968); expressed in damage to the functional potentialities of the sympathetic-adrenalin system [content of cathecholamine in urine after adrenaline and insulin loading, and of several other mediators of the nervous system (histamine, etc.)].

The effect of a SHF field on the sympathetic-adrenalin system is also shown in an experiment revealing changes in the bioelectric activity in postganglion sympathetic fibers and a change in the structure of the cerebral

part of the adrenals. Evidently, the basis of the developing pathological process is found in disturbances in the regulatory function of the nervous system with changes in hormone ratios, especially in the hypothalamus-pituitary-adrenal system. /24

As has been shown by V. V. Sokolov and N. A. Chulina [1964, 1968], the prolonged effect on people of microwaves (MCW) with an intensity not accompanied by a thermal effect causes unstable changes in the morphological condition of the blood, which nevertheless make it imperative to assume damage to the regenerative process in blood-forming tissue. This is expressed in changes in the division of bone-marrow elements, which is shown in a tendency toward an increased number of mitoses and a small number of cells with chromosome damage.

In response to the prolonged effect of microwaves with intensity not causing a thermal effect, some instability in blood indices is noted with respect to peripheral blood. Along with moderate leukopenia, in the examined individuals there was also noted a tendency toward increased amounts of leukocytes and reticulocytes [V. V. Sokolov, M. N. Ariyevich, 1960]. Dynamic observations of blood changes under the effect of low-intensity HF, UHF and SHF indicate their lability and are characterized by slight shifts with respect to hemopoiesis with a tendency toward cytopenia.

There is no doubt that microwaves can affect the eyes. S. F. Belova and Z. V. Gordon showed in 1956 that high intensities (100 $mW/cm^2$ and 40 $mW/cm^2$) after only several radiation sessions cause dimness of the crystalline lens.

The elastotonometry method, which detects the presence of a reflex controlling intra-ocular pressure existing under the control of subcortical points and the cerebral cortex, was used by S. F. Belova [1960] to reveal damage to ophthalmic tone in irradiated animals. These disturbances, according to the author, develop as a result of disorganized regulation of intra-ocular pressure and are transitory. Later, S. F. Belova [1968] showed that interrupted /25

radiation (30" radiation and 90" pause) in chronic testing (9 mos. of 1 hour radiation daily) causes crystalline lens injury in rabbits that is more pronounced and develops sooner than that produced by uninterrupted radiation of the same intensity.

An understanding of the pathogenesis of the disease, determined by chronic low-intensity radiation, resulted in classifying this disease and assigning it to an independent nosological form of "radio-wave sickness."

E. A. Drogichina [1960], M. N. Sadchikova [1959, 1960], E. A. Drogichina and M. N. Sadchikova [1964], making dynamic observations over the period of several years on workers subjected to radio-frequency radiation — SHF, HF, etc., — in factories established the developmental stages of the disease and distinguished separate syndromes of the effect of radio frequencies.

Two syndromes were determined by the authors in the initial stage of the disease: vegatative and asthenic. Characteristic of the vegetative syndrome is the vagotonic direction of the reaction toward the cardio-vascular and vegetative nervous system (sinus bradychardia, arhythmia, changes in heart conductance, arterial hypotonicity, hyperhydrosis of the hands, etc.). The authors considered these to be specific reactions developing in response to the effect of a given factor. The asthenic syndrome is related to the number of nonspecific, but constant reactions to radio waves, and develops as a result of exhaustion of higher centers of the central nervous system. This is manifested in heightened fatigue, headaches, drowsiness during working time, etc.

Prolonged work under the effect of radio waves leads to the 2nd stage of /26
the disease, which is characterized by the astheno-vegetative syndrome, often with neurotic symptoms.

This syndrome is characterized by aniospastic symptoms (headaches, pains in the region of the heart, a tendency toward spasms in the peripheral vessels). More pronounced are changes with regard to vegetative innervation,

indicating significant vegetative instability and heightened excitability of its central sections.

Further progression of the process leads to the development of the third stage of the disease in which, as in the first, two syndromes were noted: the angiodistonic syndrome, characterized by headaches, severe fatigue, sleep disturbances, memory and attention, and the diencephalic syndrome, which develops in more severe forms and is characterized by paroxysms.

According to the data of Z. A. Ginsburg [1964] definite changes in bioelectric activity accompany pronounced clinical symptoms in individuals subjected to the effect of a SHF field in industry.

Ye. A. Ginsburg and M. N. Sadchikova [1964] show that the disturbed brain /27
biopotential patterns are not random, but are correlated with the clinical pattern of the disease expressed. They are most marked in patients with pronounced symptoms of centimeter wave action. EEG changes were not detected in persons with initial SHF symptoms. But in some cases they could be provoked by hyperventilation or rhythmic photo-stimulation. Changes in bioelectric activity are manifest on the EEG by bilaterally synchronized paroxysmic activity with a wide area of distribution, and are represented primarily by flashes of theta and delta waves. They indicate that subcortical structures are involved in the pathological process (possibly diencephalic structures).

Changes in the nervous system were also detected in subjects under the influence of nonthermal, microwave radiation. These changes were expressed by functional shifts in the inhibiting effect which appeared as lowered excitability and reactivity of cortical cells, a general decrease in electrical activity in the cortex, and frequently a heightened lability. Also noted were combinations of decreased excitability and heightened lability. Besides this, brief normalization of the EEG was observed in those persons stimulated by a flickering light.

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Increased chronaxy in individuals subjected to very low-intensity radiation (10 $\mu W/cm^2$) indicates intensification of the inhibitory process. In those subjected to radiation of an intensity of 5 $mW/cm^2$ throughout the entire working day with sufficiently prolonged pauses, a reverse pattern was noted — chronaxy was shortened, which, in the words of the authors, indicates intensification of the excitation process [Yu. A. Osipov, G. V. Kalyada, Ye. A. Kulikovskaya, 1962]. Ye. A. Lobanova and Z. V. Gordon [1960] conducted studies on the effect of SHF on the functional state of the olfactory analyzer as one of the indicators of the condition of the central nervous system. These data, as well as the results of clinical examinations, indicate a lowering of the excitability of the central nervous system.

The effect of electromagnetic waves in the radio-frequency range on vascular tone in man and experimental animals has been shown by many researchers.

Not dwelling at length on reactions caused in man by the effect of radio waves of various ranges, we shall only mention that in the HF, UHF and SHF ranges a hypotensive effect in those working with radio-wave sources has been described by a number of authors who observed the predominance of vagotonic reactions with a tendency toward hypotonicity [I. A. Abrikosov, 1958, M. N. Sadchikova, A. A. Orlova, 1958, A. A. Orlova, 1960, A. N. Obrosov and V. G. Yasnogorodskiy, 1961].

## 3. Experimental Studies

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Biological effects, caused by EMF in radio-frequency ranges, were first studied under high-intensity radiation (thermal effect); then it was gradually lowered and in recent years it has decreased by three orders of magnitude in comparison with the threshold of the integral heat effect for super-high frequencies, and by 1-2 orders of magnitude for other ranges.

TABLE 3. LIFETIME OF ANIMALS IN-RADIO-WAVE RADIATION OF VARIOUS RANGES

| Wave range | Intensity of radiation | | Time (minutes) and % of animals' death | |
|---|---|---|---|---|
| | Field strength and PPM* | Energy density ($erg/cm^3$) | 50% | 100% |
| Medium (500 kc) | 8000 V/m | $2830.10^{-6}$ | — | — |
| Short (14.88 Mc) | 5000 V/m | $1100.10^{-6}$ | 100 | |
| | 9000 V/m | $3564.10^{-6}$ | — | 10 |
| Ultrashort 69.7 Mc | 5000 V/m | $1100.10^{-6}$ | | |
| | 2000 V/m | 176.10 | 100-120 | 130-200 |
| 155 Mc | 700 V/m | $21.6.10^{-6}$ | " | " |
| 191 Mc | 350 V/m | $5.4.10^{-6}$ | 100-150 | 160-200 |
| Microwaves Decimeter | $100 mW/cm^2$ | $33.10^{-6}$ | 60 | |
| 10 cm | " | " | 15 | 60 |
| 3 cm | " | " | 110 | |

*This designates power current density.

As the radiation intensities of waves of various ranges are expressed by different units [field strength or power current density (PPM) (volt/meter), ($\mu W/cm^2$)] the data from these studies [Z. V. Gordon, Ye. A. Lobanova, 1960; K. V. Nikonova, 1964; P. P. Fukalova, 1964] are given in units of energy density ($erg/cm^3$). At identical microwave radiation intensity (100 $mW/cm^2$

or $33.10^{-6}$ erg/cm$^3$) the animals died most quickly from the effect of 10 cm waves (15 minutes). At identical USW and SW radiation intensity (5000 V/m or $1100.10^{-6}$ erg/cm$^3$), the animals subjected to the effect of USW died in 5 minutes, but those subjected to SW died after 100 minutes. In the medium wave range (3000 V/m), many hours of radiation did not cause death in the animals, whereas 9000 V/m in the SW range led to rapid death (10 minutes) of all the animals.

Thus, when the wavelength was shortened, the energy density (PE) causing /30
death in the animals decreased to the microwave range, and then increased somewhat. Medium waves at PE of $2830.10^{-6}$ erg/cm$^3$ do not cause death in the animals for many hours, but short and ultrashort waves at significantly lower PE ($176.10^{-6}$ - $5.4^{-6}$ erg/cm$^3$) lead to the death of 50% of the radiated animals in approximately the same length of time — 100-120 minutes.

Microwaves, at identical PE, cause 50% death in the animals at varying lengths of time (15-180 minutes). Especially rapid is the effect of 10-centimeter waves. The clinical pattern of overheating follows an extremely severe course.

As has been shown by these same authors, the thresholds of thermal effect /31
are different for different wave ranges.

Table 4 gives maximum radiation intensity values not causing an integral thermal effect.

It is evident from the table that, when the wavelengths are shortened, the values of energy density, when there is no increase of body temperature, continuously decrease, with the exception of the UHF range. The latter cannot be explained as yet. It can be assumed that the nature of the UHF range is determined by the resonance effect in heterogenic structures and micromolecules [Yu. Ye. Moskalenko, 1960; V. A. Franke, 1960].

TABLE 4. RADIATION INTENSITIES NOT CAUSING INCREASED BODY TEMPERATURE

| Radiowave ranges | Threshold of thermal effect | Energy density ($erg/cm^3$) |
|---|---|---|
| Medium (500 kc) | below 800 V/m | $2830.20^{-6}$ |
| Short (14.7 Mc) | 2250 V/m | $224.10^{-6}$ |
| Ultrashort | | |
| 69.7 mc | 150 V/m | $0.995.10^{-6}$ |
| 155 mc | 50 V/m | $0.11.10^{-6}$ |
| 191 mc | 20 V/m | $0.018.10^{-6}$ |
| Microwaves | | |
| Decimeter | over 40 $mW/cm^2$ | $13.2.10^{-6}$ |
| Centimeter | 10 $mW/cm^2$ | $3.3.10^{-6}$ |
| Millimeter | 7 $mW/cm^2$ | $2.31.10^{-6}$ |

One of the integral indicators of the biological effect of electromagnetic waves in the radio frequency range is the dynamics of animal weight.

There are reasons to assume that weight variation in irradiated animals (mice) depends to a considerable degree on radiation intensity and to some degree on wave range.

Low-radiation intensities in the UHF range (according to data from older works) stimulate a weight increase in the animals, and greater radiation depresses it. There are only individual works in research conducted in the SHF range: Z. V. Gordon, Ye. A. Lobanova, M. S. Tolgskaya, 1955; Ye. A. Lobanova, 1960. These indicate some stimulation of weight dynamics in the

first weeks of irradiation with a subsequent weight lag under the prolonged effect of the SHF-field. Finally, the medium wave range, according to the data of K. V. Nikonova, does not cause changes in weight dynamics in irradiated animals. /32

Table 5 gives weight changes in animals under the effect of waves in the ranges studied (according to the data of Z. V. Gordon, Ye. A. Lobanova, K. V. Nikonova, P. P. Fukalova).

TABLE 5. WEIGHT CHANGES IN ANIMALS UNDER THE EFFECT OF RADIO WAVES IN VARIOUS RANGES /33

| Wave range | Radiation intensity | Start of change (months of radiation) | Weight increase of animals (in averaged data) | |
|---|---|---|---|---|
| | | | Irradiated | Control |
| Millimeter | 10 mW/cm | 3 | 65.0 | 75.0 |
| Centimeter | | | | |
| 3-centimeter | " | 1 | 42.0 | 70.0 |
| 10-centimeter | " | 1.5 | 25.0 | 70.0 |
| Decimeter | " | 2 | 95.0 | 120.0 |
| Ultrashort | | | | |
| 191 Mc | 20 V/m | 2.5 | 125.0 | 145.0 |
| 155 Mc | 50 V/m | 3.5 | 110.0 | 128.0 |
| 69.7 Mc | 150 V/m | 4 | 182.0 | 210.0 |
| Short | 2250 V/m | 4 | 180.0 | 210.0 |
| Medium waves | 1800 V/m | 10 | no changes | |
| | 50 V/m | " | " | |

In all cases radiation intensities were used which did not cause an integral thermal effect (increase of body temperature in the rectum).

The data presented in the table verify the fact that the beginning of the weight lag in irradiated animals, in comparison with control animals, and the degree it is expressed are related to a certain degree to wave ranges.

Thus, centimeter waves have the greatest depressing effect on the animals' development (weight increase and time when it begins to decrease, in comparison with control animals). When wavelengths are increased (decimeter, ultrashort, short waves) the depressing effect is decreased. It is also decreased at extreme points of the spectrum of electromagnetic radio frequency waves (millimeter and medium waves). However, in the millimeter range it begins much later than in other ranges (beginning in the 3rd month of radiation) and reaches a maximum decrease after 6 months (45 g lower than in the control animals). In the medium-wave range, the weight lag in irradiated animals, in comparison with control, was statistically unreliable. /34

Experimental studies on animals, conducted in various radiowave ranges [Z. V. Gordon, 1960, 1964; K. V. Nikonova, 1964; P. P. Fukalova, 1968] verify that the chronic effect of various radio frequency ranges of nonthermogenic intensity causes a steady decrease in the blood pressure level. This often precedes the phase of increased pressure (Table 6). /35

Whereas a steady decrease in the blood pressure level is common for the effect of waves of all ranges, there are also distinguishing individual range changes:

1. Absence of the first phase — increased pressure level in animals irradiated with medium, 3-centimeter, and millimeter waves.

2. Rapid development of the first phase (1st week of radiation) in the decimeter and 10-centimeter wave ranges.

3. Early development of the second phase of decreased pressure level in the UHF (69.7 Mc) and SW ranges in the 6th week of radiation.

4. Intensive decrease in the blood pressure level, especially in the millimeter, 3-centimeter and UHF — 155 and 191 Mc ranges (20%-33%).

TABLE 6. BLOOD PRESSURE LEVEL CHANGES IN RADIO WAVE RADIATION

/36

| Wave range | Radiation intensity | Phase I increased pressure (weeks) | Phase II decreased pressure (weeks) | Pressure decrease (in %) |
|---|---|---|---|---|
| Medium (500 kc) | 1800 V/m | unreliable | | |
| | 5 A/m | -- | 30 | 11.7 |
| Short (14.8 Mc) | 2250 V/m | 2 | 6 | 12.0 |
| Ultrashort 69.7 Mc | 150 V/m | 2 | 6 | 17.0 |
| 155 Mc | 50 V/m | 2 | 12 | 33.0 |
| 191 Mc | 20 V/m | 4 | 12 | 29.0 |
| Microwaves | | | | |
| Decimeter | 10 10 $mW/cm^2$ | 1 | 10 | 17.0 |
| Centimeter 10 cm | " | 1-6 | 22 | 11.0 |
| 3 cm | " | -- | 6 | 25.0 |
| Millimeter | " | -- | 4 | 20.0 |

It is known that in the mechanism of vegetative-vascular disturbances great importance is attached to the hypothalamic sections of the brain.

The participation of the hypothalamic area during the action of radio waves is indicated by a study of the influence of microwaves on specialized forms of appetite and electrolytic exchange in irradiated rates. /37 As is known, the higher centers regulating water-salt exchange are individual nuclei of the hypothalamus. V. V. Kulakova (1968) revealed the differing changes between the degree to which certain forms of salt appetite are expressed and electrolytic composition — in the organism. This difference is possibly connected with disturbance of the mechanism controlling distribution of salt and water between the cell and the internal medium.

The significant participation of the hypothalamic region is indicated by the clinical pattern of severe chronic influence of electromagnetic radio-frequency fields which is characterized by the diencephalic syndrome [E. A. Drogichina, M. N. Sadchikova, 1964].

## The Effect on the Central Nervous System

The first report on the effect of MCW (cm, ranges) on the conditioned-reflex activity of experimental animals and other functions was made by Z. V. Gordon, Ye. A. Lobanova, S. F. Belova and M. S. Tolgskaya in 1955 at a conference on questions of dosimetry and hygienic evaluation of electromagnetic fields in working with high and medium frequency generators. It was frequently stated in the report that, when rats were irradiated with nonthermogenic intensity MCW, phase changes in the central nervous system excitability were observed.

Using the motor-food method, Ye. A. Lobanova [1955, 1959, 1960] has shown /38 that, under the chronic effect of centimeter waves (10 $mW/cm^2$ for 60 min. daily), the character of the initial changes in the conditioned-reflex activity in the animals was to a significant degree determined by the individual natures

of the central nervous system (CNS). In animals with a strong excitation process, a brief phase of increased excitability was observed; in animals with a weak excitation process, excitability of the CNS decreased from the first session.

When radiation was prolonged, individual characteristics of the CNS affected the depth of shifts in conditioned-reflex activity. Nevertheless, in all the animals changes in the conditioned-reflex during a certain length of time were undulating in character — periods of disturbed conditioned reflexes alternated with periods of normalization. Subsequently, as a result of reduced capacity for work of the nerve cells and weakened function of the higher sections of the CNS, a drowsy state developed.

Changes in the conditioned-reflex activity of rabbits under the same radiation conditions did not essentially differ from those described in rats. By the end of the radiation period (4 months) the functions of the higher sections of the CNS were severely damaged, but in approximately half a month they were normalized.

M. S. Tolgskaya [1960] has shown that functional changes in the CNS are /39
based on inverse morphological changes in axodendritic and axosomatic shifts.

Studying the effect of millimeter and decimeter MCW of nonthermogenic intensity on the conditioned-reflex activity of rats, Ye. A. Lobanova [1964], recorded in all the animals (unlike with centimeter waves) a prolonged phase of increased CNS excitability, which subsequently alternated with a phase of weakened excitation.

A. G. Subbota [1958] after the single action of low-intensity centimeter waves (5 $mW/cm^2$) observed intensification of the excitation process in dogs. After repeated actions, the conditioned-reflex activity was equalized.

Radiation of various kinds of animals (mice, rats, rabbits, dogs) with MCW of thermogenic intensity, according to the data of all the authors

[A. G. Subbota, 1958; S. F. Gorodetskaya, 1960, 1964; Ye. A. Lobanova, 1966], led to a weakening of the excitation process, which was reflected in disturbances in the newly-developed conditioned reflex, as well as of reduced stability of fixed conditioned reflexes. Thermogenic levels of radiation (from 40 $mW/cm^2$ in some studies to 400 and more $mW/cm^2$ in others) only affected the depth of these shifts, and were not essential in determining their character.

However, although after single actions, conditioned-reflex activity was /40
normalized in 5 days, even at the maximum radiation level [S. F. Gorodetskaya, R. I. Kruglikov], more than 2 months were necessary for normalization of conditioned reflexes after chronic radiation for 4 months at the minimum level.

Thermogenic radiation of rats was used by Ye. A. Lobanova [1966, 1968, a,b,c] to study the effect of pulsed and continuously generated centimeter waves, as well as the continuous and interrupted action of MCW on fixed conditioned reflexes. The author did not indicate the principal differences in the changes in conditioned reflexes under radiation by pulsed and continuous MCW. Attention was only given to the more pronounced weakening of the excitation process in the initial period of pulsed MCW action.

A study of conditioned vegetative reflexes (cardiac and respiratory) in rabbits under nonthermogenic (5 $mW/cm^2$) and thermogenic (to 100 $mW/cm^2$) intensity MCW radiation in the cm range was made by M. I. Yakovleva [1968], who ascertained the high resistance of these reflexes during single and even repeated actions. Under the effect of repeated radiation of mice with cm. waves at relatively low intensities (5-15 $mW/cm^2$), M. I. Yakovleva, et al. /41
[1968] observed changes in the morphological and functional state of cortical neurons, which preceded changes in conditioned vegetative reactions.

The effect of USW and SW on the activity of higher sections of the CNS has been studied to a lesser extent.

Changes in conditioned reflexes in birds, rats, rabbits and dogs as a result of the effect of UHF and HF were observed by N. N. Livshits [1955, 1957]; T. N. Promtova [1956]; B. A. Baronenko, K. F. Timofeyeva [1958, 1959]; and Ye. A. Lobanova [1968].

In spite of a well known discrepancy in these data, which is accounted for by differences in radiation methods, dosage, and length of radiation, the basic conclusion which results from analyzing them is that, at the beginning of the action, intensification of the functions of the higher sections of the CNS are possible, and then, with repeated actions, they are decreased.

The attempts of several authors to use EMF as a conditional stimulus are especially noteworthy.

G. F. Plekhanov, and V. V. Vedyushkina [1966] succeeded in producing conditioned reflexes in man to high-frequency EMF (735 cps). In contrast to conditioned reflexes to adequate stimuli (light, sound), conditioned reflexes to EMF appeared, were established later, and were less stable.

The same characteristic was found in the conditioned reflex of mice in a superhigh frequency EMF — 20 $mW/cm^2$ and in fish in an ultrahigh frequency EMF with an intensity of 500 V/m [Yu. A. Kholodov, 1966]. /42

Consequently, EMF as a stimulus is weaker in comparison with adequate stimuli in producing conditioned reflexes.

Summing up this section, it can be noted that the character and depth of shifts detected in conditioned-reflex activity in animals under the effect of radio waves are determined by many factors, including individual CNS characteristics, the kind of animal, the effective range, the intensity, duration and regime of radiation.

Nevertheless, the most frequent effect of radio waves is depression of functions of higher sections of the CNS. It has been shown that morphological changes in neurons and interneuron connections precede and accompany functional changes in the CNS.

## Electro-physiological Studies of the Biological Effect of Microwaves

Experimental study of the biological effect of microwaves by means of electro-physiology was begun in the 1950's. In the last decade (from 1960 to 1970) a large amount of electro-physiological works have appeared in the USSR devoted to phenomenology and the physiological mechanism of microwave action.

All these studies were based on distinguishing between the thermal and nonthermal effects of microwaves. /43

a) Thermal effects of microwaves

M. S. Byskov and Z. Ye. Moreva [1960] studied in a neuromuscular frog specimen changes in excitability and conductance of the nerve and altered muscle currents. The data obtained indicate the development of the classic Vvedenskiy parabiosis in the nerve under the influence of radiation.

Subsequently, this conclusion was verified by M. S. Bychkov using chronaximetry, a study of the nerve's ability to adapt to electromyography

The works of Yu. A. Kholodov and M. N. Zenina, 1964; Z. M. Gvozdikova et al, 1964; V. N. Zenina, 1964, verified the primarily deactivating influence of the thermal effect and the phase character of electroencephalographic (EEG) changes. The researchers also completely agree that the EEG changes are polymorphic. Generalizing all the existing data, it must be noted that the most characteristic manifestations of the deactivating effect are synchronizations of fluctuations with their moderation and, in far-gone cases,

flattening of the curve. With comparatively weaker thermal effects, a desynchronization reaction can be observed.

b) Nonthermal effect of microwaves. /44

The first mentions of changes in electro-physiological indices under the effect of low-intensity microwaves (100 - 5000 $\mu W/cm^2$) appeared in 1959. In subsequent years, the study of the nonthermal effect of microwaves has gradually occupied the central role in electrophysiological studies of this factor. It has been conducted at various levels of vital activity — from cellular to system and intersystem relationships.

Research using microelectrode techniques [M. S. Bychkov, 1967] has added a number of theoretically important factors, characterizing changes in isolated stimulated structures.

This is primarily related to establishing in a neuro-muscular frog specimen the following facts (as applied to PPM on the order of 5 $\mu W/cm^2$).

1. The hyperpolarizing effect of microwaves (studies of the membrane potential of muscular fibers).

2. The increase in the excitation threshold of a single nerve fiber.

3. The extension of the latent and refractory periods in a single nerve fiber.

4. The increase in the excitation rate in a single nerve fiber.

5. Decrease in the amplitude of action potentials in a muscular fiber /45 (indirect stimulation)

6. Increase of synaptic delay in the myoneural synapse.

M. S. Buchkov [1967] also established the depression of spontaneous pulse activity of single neurons in the isolated and nonisolated nerve ganglion of medicinal leeches.

The development of changes in the CNS of warm-blooded animals and man under the effect of extremely low-intensity microwaves (including such slight test values as 20 $\mu W/cm^2$) is not doubted by any of the electro-physiologists studying this question. The data obtained to the present time include changes in both fast (commisural) and slow (total) activity of the brain, especially EEG changes.

Studies of spontaneous pulse activity in single neurons of a cat's somatic-sensory cortex [M. S. Bychkov, 1967] have shown that this form of activity is depressed at a PPM of 20 $\mu W/cm^2$. In narcotized cats, afferent volleys* were also depressed (primary response, commisural type of neurons) in the same section of the specific projection system, whereas in the reticular /46
nucleus of the thalamus an increase of background pulse activity was observed in combination with variable intensification of the primary response. Induced commisural activity of neurons of nonspecific thalamus also changed insignificantly in different directions in different tests.

Thus, the well-known dissociation was observed in the combined activity of specific and nonspecific systems of afferent information transmission.

EEG changes were studied at various PPM. It is characteristic that the effectiveness of radiation, which decreases with lowered PPM, in the least intensive of the studied fields (PPM — 20 $X/cm^2$) again increases [Z. M. Gvozdikova et al., 1964]. This is tentatively considered by the authors to be an intensification of the preliminary reaction to a stimulus of near-threshold intensity.

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*Translator's Note: This designates rhythmical succession of muscular twitches artificially induced.

Concerning concrete phenomenology of EEG changes, the researchers [M. S. Bychkov, Yu. A. Kholodov, Z. M. Gvozdikova et al.,I. N. Zenina et al.] agree that the following variants occur:

1. Changes toward predominantly slow rhythms and increased "spindle" activity.

2. Synchronization and hypersynchronization reactions.

3. A decrease in the amplitude of the basic rhythm and general depression of electric activity (including possible flattening of the curve).

4. Changes toward predominantly fast rhythms and desynchronization reactions. /47

The predominant variation of EEG changes, especially under the effect of pulse radiation, is a certain manifestation of deactivation. After interception at the mid-brain level, strychnine-type discharges can be observed [Yu. A. Kholodov and I. N. Zenina, 1964]. The isolated brain (cerveau isolé specimen) is more sensitive to radiation than the intact brain [Yu. A. Kholodov and I. N. Zenina, 1964; Yu. A. Kholodov, 1966].

Along with basic reactions to radiation, brief desynchronization reactions are observed in switching a generator on and off [Yu. A. Kholodov and I. N. Zenina, 1964; Yu. A. Kholodov, 1966], which Yu. A. Kholodov considers to be orienting reactions. It has been shown [I. N. Zenina] that they cannot be explained by sound stimulations developing during the operation of the generator.

In a number of cases in tests on rabbits under repeated irradiations, the development of paroxysmal bioelectric activity has been observed in the form of single and multiple high-amplitude acute waves and peaks, hypersynchronized waves [I. N. Zenina, 1964], and intermittently developing convulsive discharges

of the "strychnine" type [Yu. A. Kholodov, 1966]. Paroxysmal activity developed very often in sensory and electromagnetic provocation [I. N. Zenina, 1964], after the injection of caffeine [Yu. A. Kholodov and I. N. Zenina, 1964], /48 and with increased sensitivity to microwaves of cortical-subcortical structures after interception at the mid-brain level [Yu. A. Kholodov, 1966].

Curves of the sensitivity of the central nervous system to microwave activity, determined from the dependence of the average latent period of EEG changes on PPM, are close to the classical Weiss*-Lapin curve [Z. M. Gvozdikova et al., 1964].

Electro-physiological data provide a basis for assuming that microwaves affect the central nervous system both by directly affecting the brain substratum [Yu. A. Kholodov, 1966] and by reflex means. At least in animals of small and medium size, the first mechanism is the dominant one.

A number of electrophysiologists' reports consider the physiological mechanism of the microwave effect in the central nervous sytem from the aspect of intercentral and intersystem relations. In particular, the role of subcortical-stem structures is indicated in the pathogenesis of the microwave effect [Yu. A. Kholodov, 1966], as well as the well-known dissociation in the combined activity of specific and nonspecific afferent systems in the brain [M. S. Buchkov, 1967, R. I. Kruglikov and M. P. Troyanskiy, 1967]. This supports the hypothesis of clinicists about the diencephalic genesis of dominant neurological shifts.

Besides experimental data obtained from animals, there is also material /49 from electroencephalographic studies of people.

The studies of E. A. Drogichina [1960] were the first; their results were then repeatedly verified, more precisely defined and detailed in the works of R. A. Ginzburg and M. N. Sadchikova [1964],N. V. Tyagina [1965], M. P. Troyanskiy et al. [1967].

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*Translator's Note: This refers to Moriz Weiss, a physician from Vienna.

The data of the authors cited above indicate the predominance of moderately expressed changes (primarily deactivating) both over initial appearances and over-prounounced changes. They also indicate a correlation between EEG changes and the stage of operation in SHF electromagnetic fields.

Let us dwell briefly on individual new problems which have been solved in recent years.

The role of individual sections of the nervous system (NS) in the development of the pathological process has been successfully recorded.

Here, the data obtained also presuppose the participation of the intermediate brain in the organism's reaction to radiation. Therefore, special attention has been given to the study of the nervous system, to cholinergic processes important in understanding the pathogenesis of disturbances in nervous activity, and the reactivity of the nervous system.

As is known, the basic component of cholinergic processes is acetylcholine /50
with cholinesterase which acts on it and whose activity is determined in accordance with the accumulation of acetylcholine.

S. V. Nikogosyan and I. A. Kitsovskiy [1969] obtained persuasive data on the effect of low intensities of radiation, indicating decreased activity of cholinesterase in the large hemispheres and stem section of the brain, increased acetylcholine content in the large hemispheres, decreased sulfur-hydrile, (SH)-groups in the stem section of the brain, an increase of Na ions and a decrease of K ions in the large hemispheres and stem section of the brain. The excitability of N-cholinoreceptors is reduced, while the state of the M-cholinoreceptors remains unchanges. This suggests a selective effect of the factor on cholinergic structures and can disturb to a significant degree excitation transmission in the central nervous system.

The effect of MCW radiation on the diencephalic region can also be verified by changes in brain biopotentials of radiated animals against a background

of the effect of convulsive substances (cardiosols), whose point of application is the hypothalamus. As shown by I. N. Zenina [1964], under the effect of radiation, blocking of subconvulsive bioelectric activity is observed. This gives rise to the assumption that cardiosol excitation and the effect of radiation have a common means of development and distribution.

The discrepancy in changes in irradiated animals between the degree to /51
which certain forms of salt appetite are expressed and the electrolytic composition in the organism, discovered by V. V. Kulakova, is possibly related to disturbed regulation of the activity of the hypothalamus region. This might also be indicated by the altered blood pressure level, proceeding in two phases, and by the corresponding changes in the accumulation of neurosecretion observed at that time in nerve cells and tissues of the hypothalamus region.

The noted shifts under the effect of low-intensity MCW (such as changes in cholinergic processes and bioelectric activity of the brain, the lack of agreement between water-salt appetite and the electrolytic composition of the medium, changes in blood pressure level and the neurosecretory function in cells and tissues of the hypothalamus region, and a number of other indices, as well as clincial data) point to the decisive role of the hypothalamus region in reactions of the nervous system to radiation.

It was obviously important to ascertain which is the primary mechanism of certain neurohumoral shifts and if, for example, a change in the activity of cholinesterase is the result of changes at the molecular, cellular level, or whether the entire organims, with its complex system of regulating internal processes, is necessary for the effect. As has been shown by the studies of V. M. Shtemler in vitro and in vivo, the possibility of a direct effect on the structure of the enzyme molecule is absent, i.e., evidently, decreased activity /52
of cholinesterase in the blood is a secondary effect.

The development in recent years of the study of the immunobiological reactivity of the organism in comprehensive research on disease pathogenesis

is extremely advantageous, as it makes it possible to recognize the organism's reactions to low-intensity radiation at early stages.

We already have a basis for assuming the resistance of the organism is lowered in radiation, considering the past works of Nikogosyan [1964], Gel'fon and Sadchikova [1964], which indicate pronounced shifts in albuminous fractions of the blood.

The works of Ye. I. Smurova and A. P. Volkova [1968], as well as those of B. A. Chukhlovin [1968], I. S. Dronov [1968], and Smurova [1968] have shown a decrease in antibody formation in the immunization of animals, and disturbed phagocytic and bactericidal functions of the blood.

Of great theoretical and practical importance is the development of studies of the sexual system of irradiated animals and the postnatal development of offspring. On this plane, the works of A. N. Bereznitskaya [1969]; S. I. Gorodetskaya and M. A. Lobova [1968]; M. P. Troyanskiy and P. I. Kruglikov [1968] are very important. /53

The researchers all arrive at a unanimous conclusion about the functional changes in the sexual system of irradiated animals, expressed in a disturbed estrous cycle in females and disturbed reproductive functions in males and females, a decrease in the number of offspring and a lag in their development in the embryonic and postnatal period. As shown by the studies of Bereznitskaya in radiating female animals in various pysiological conditions — those most sensitive to the effect were mice which at the beginning of the radiation period were in the pubescent stage, and sexually mature animals, irradiated before and during pregnancy, especially the latter.

Somatic defects, disturbed functions of higher sections of the CNS in prenatally irradiated animals, functionally inadequate activity of the pituitary gland, pronounced changes in nuclein exchange in sexual organs, delayed

results (in 2 - 3 generations) of the effect of MCW and UHF, disturbed embrogenesis — these all suggest possible genetic effects.

This places before researchers the definite and complex practical task of /54
protecting female labor, especially, and teenagers from the possible effect of radio-frequency EMF. In relation to this, in the USSR health rules have been amended which forbid women during pregnancy and teen-agers from working with sources of electromagnetic fields in the radio-frequency range.

Morphological changes in animals irradiated by electromagnetic waves of various radio-frequency ranges at high intensities present a very similar pattern, and in severe testing cause overheating of the organism with morphological changes characteristic of hyperthermy. The chronic effect of moderate intensities causes some dystrophic processes with vacular disorders and damage to the vegetative centers and ganglia. This is accompanied by the mobilization of elements of the reticulo-endothelial system in general, and especially in the brain. Low intensities primarily cause a moderate proliferative reaction of the reticulo-endothelial system.

A broad front of morphological studies is being undertaken in the /55
Academy of Medical Sciences of the USSR (AM SSSR) [M. S. Tolgskaya, Z. V. Gordon, 1960, 1964, 1968; K. V. Nikonova, 1964; P. P. Fukalova, 1968].

In comparing morphological changes which develop under the effect of radio waves of various ranges (ultra-short, short and medium microwaves), one can say that under the acute effect of great intensities of any range, differences in morphological changes in the organs and tissues of the irradiated animals are "obliterated" in relation to a rapid lethal outcome and the predominance of pronounced vascular disorders. However, it must be noted that 10-centimeter waves have the most pronounced effect. A lethal outcome develops very rapidly, the pattern of overheating in the organism is especially pronounced, and death occurs much sooner. The decimeter range is second. Third

are the shortest USW and SW, then comes the millimeter range, and in the very last place are medium waves, which even at comparatively great intensities are not able to cause overheating in the organism and death of the animals. The changes detected in animals are primarily related to overheating. However, despite the fact that the thermal effect conceals more delicate shifts, all the /56
changes detected under the effect of great intensities must not be attributed to the thermal effect alone.

Individual changes (changes in receptors, histochemical changes in the skin) indicate a difference in the effect of radio waves of various high-intensity ranges.

For example: Under the effect of the decimeter range, the receptor apparatus in the skin does not change, but the interoceptors of the internal organs are more severely affected. Under the effect of the millimeter range, receptors in the skin are affected especially strongly, while there are lesser changes in the interoceptors. Under the effect of the ultrashortwave (USW), shortwave (SW) and 10-centimeter wave ranges, the receptors in the skin and the interoceptors are affected approximately equally.

Of special interest are the morphological changes in various organs and systems under the effect of various low-intensity wave ranges (not causing an integral thermal effect).

It must be noted that in low-intensity radiation (just as at high-inten- /57
sities) certain features are observed which are characteristic of each wave range. Under the effect of centimeter and especially millimeter wave ranges, the greatest changes were observed in skin receptors, whereas under the effect of decimeter range and HF-range waves the skin receptors remained intact [M. S. Tolgskaya, Z. V. Gordon, 1960, 1964].

Skin receptors and interoceptors of the internal organs are also changed equally in USW and SW radiation [M. S. Tolgskaya, P. P. Fukalova, 1968].

Predominant injury to skin receptors or interceptors could not be noted under USW and SW radiation. Interoceptors of the internal organs were thus affected in nearly all wave ranges with the exception of the millimeter range.

Clearly evident deformation of apex dendrites of pyramidal neurons in the brain was equally pronounced in all wave ranges. A decrease was observed in the content of ribonucleoproteids and protoplasm in the cells of the internal organs, skin, and nervous system.

A decrease in the ribonucleoproteide content in the epidermis of the skin and its derivatives was most pronounced under the effect of centimeter and especially millimeter ranges. The normal amount of ribonucleoproteids was preserved in skin radiated by decimeter waves. /58

All the above-mentioned findings indicate that histochemical methods, as well as refined methods of studying the nervous system, make it possible to detect initial functional shifts in fine structures of the nervous system and in the protein exchange of cells which ordinary morphological methods cannot detect.

Under a more prolonged effect (to ten months) added to the above-mentioned changes are small dystrophic changes in nerve cells of the brain in the form of pycnomorphic wrinkling of individual brain cells and turbid swelling with the appearance of vacuoles in the protoplasm of individual nerve cells of the hypothalamic region, as well as disturbed neurosecretory activity of the hypothalamus-pituitary system. The latter indicates that in prolonged radiation with all the above-mentioned low-intensity wave ranges, the cells of the hypothalamic region are especially affected. This coincides with clinical symptoms in animals in the form of decreasing blood pressure. Summarizing the above, it must be emphasized that damage to the nervous system is in first position. Second is damage to muscular fibers of the mycardia, taking the form of uneven coloring, and sometimes swelling and fragmentation of individual muscular fibers of the mycardia. Under /59

very prolonged radiation poorly expressed protein dystrophy is noted, and vacuolization of the protoplasm of individual liver cells and the epithelium of individual convoluted tubules of the kidneys. In some animals (mostly under the effect of the decimeter range) adipose dystrophy was observed in individual groups of kidney cells.

Against a background of slight dystrophic changes in nerve cells, reproduction of microglia in the brain is noted with slight dystrophic changes in individual microgliocytes (under the effect of decimeter waves).

A proliferative reaction of reticulo-endothelial elements in the liver and kidneys is also detected, in the liver leading to the formation of submiliar histiocytic nodules.

Consequently, under prolonged radiation with low-intensity electron microscope (EM) waves of various ranges, the observed dystrophic changes in the nervous system and internal organs (detected by ordinary morphological methods) are accompanied by proliferative, histiocytic reactions in the internal organs and by reproduction of microgliomas in the brain. This indicates compensatory-adaptive processes in the organism. /60

Under still more prolonged radiation by electromagnetic waves (up to ten months) in all the above-mentioned low-intensity ranges, dystrophic changes were discovered in the seminiferous epithelium of the testicles, especially pronounced under the effect of decimeter and centimeter range waves (from the group of microwaves) and then under the effect of USW, SW and HF fields. However, only individual ducts of the testicles are affected; spermatogenesis in the bulk of the ducts is preserved, and the animal is capable of fertilization.

In summarizing the above, it must be emphasized that in radiation by millimeter waves, primary damage to skin receptors and histochemical changes in the skin were discovered.

Radiation with centimeter waves causes significant histochemical changes and changes in the receptor apparatus of the skin with changes in the interoceptor apparatus and interneuron connections of the cerebral cortex. The effect of decimeter range waves causes primary damage to the interoceptor /61
apparatus of the internal organs with no changes in the receptor apparatus of the skin. This also corresponds to great morphological changes in the internal organs found in studying the material with ordinary morphological methods.

In low-intensity USW and SW radiation, as well as with medium waves, however, the skin receptors and interoreceptors of the internal organs are also affected.

It can be assumed that millimeter waves are absorbed in the surface layers of the skin, and all dystrophic changes in the internal organs are related to the neuroreflex mechanism. Decimeter waves, penetrating deeper, can also have a direct effect on internal organs and the brain — leaving the skin intact. Centimeter waves, partially absorbed by the skin, can cause changes in it, as well as changes in more deeply located tissues.

Evidently, under the effect of low intensity waves, the following occurs: on one hand, deep penetration of waves and a direct effect on organs and tissues (which is especially prounced in the decimeter range), and on the other /62
hand, stimulation of the peripheral neuroreflex apparatus with a reflex effect on internal organs and the nervous system (millimeter range).

M. A. Aleksandrovskaya and R. I. Kruglikov [1968], in a morphological study of the brain of rats irradiated with athermal-intensity MCW, discovered activation of all kinds of neuroglias with nerve cells preserved. They also observed hyperplasia of capillaries and precapillaries, in which the number of pericytes was increased. The authors consider the morphological changes they observed to be the result of changes in the functional condition of higher sections of the CNS, developing under the influence of radiation.

One of the tasks was to study the combined effect of electromagnetic waves in the radio-frequency range with other industrial factors of the environment. It is hardly necessary to mention the advantage of these studies, as it is completely evident from hygienic research. The works of K. V. Nikonova and N. D. Khramova [1968] showed that a number of integral indices, as well as the condition of pheripheral blood and the CNS, can indicate the presence of /63
synergism in the action of a SHF field and soft X-rays. Studies are continuing to discover the character of the combined action of SHF and soft X-rays under chronic action at low intensities.

Finally, in recent years the problem of the biological effect of low-intensity electromagnetic radiation has become very important in establishing threshold values of radiation intensity for individuals spending a long time in an electromagnetic field. This also includes those who by the nature of their work are not connected with radiation sources, as well as the population.

## SECTION III

## III. THE EFFECT OF ELECTRICAL FIELDS ON THE HUMAN ORGANISM AND ANIMALS

In this review we are limited to considering the biological effect of a static electric field (SEF) and a low-frequency electric field (EF), keeping in mind the industrial frequency (50 cps) and frequencies close to it. In this case, between the condenser plates, where the object being studied is usually placed, the EMF is not yet formed, and we can consider the primary /64
action of the electric component.

Beyond the scope of our attention are questions related to the role of the EF created by biological objects, in processes regulating the physiological functions within the organism and between organisms [Chernova, 1965; Presman, 1968; Gulyav et al., 1969]. There are some works on the influence of an EF on

the biological object in modern Soviet literature (above 100). These have appeared in a wide variety of publications, so that it is difficult to guarantee a complete survey. In a summarizing article, one author [Solov'yev, 1962] complains that the low-frequency EMF range is an area undeservedly forgotten both in explaining the biophysical mechanisms and in the practical aspects of diagnostics, therapy and prophylactic measures.

It must be admitted that in the last seven years the situation in this field has not changed much, and the existing progress is more quantitative (the number of works describing the biological effect of EF has increased) than qualitative. However, the very fact that the number of phenomenological /65
works increased can clear up some aspects of the mechanism of the action of EF.

## Therapeutic Use of Electrical Fields

Although the practical use of EF for medical purposes has been widely employed for almost two hundred years, the therapeutic application of this physical factor has still not received a complete theoretical explanation. In physiotherapy, the method of using the therapeutic action of a static electric field (SEF) is known as franklinization. It must be borne in mind that in electro-therapeutic procedures, not only the EF affects the organism, but air ions and ozone as well. It is even believed that the EF does not have a biological effect, and only air ions affect the organism [Vasil'yev, 1953; Chizhevskiy, 1960; Portnov, 1960 et al.].

On the other hand, since the end of the last century, physiologists have convincingly demonstrated the biological action of low-frequency EF, using as an object of study a neuromuscular specimen from a frog [Danilevskiy, 1900 et al.].

Studying the contraction of the neuromuscular specimen in a low-frequency EMF, F. P. Petrov in a series of works [1930 - 1953] observed and described

certain dependencies of the reactions studied on EF parameters. The optimum EF frequency for this reaction was a frequency of 50 cps. Lowering the frequency to 5 cps decreased the intensity of the reaction by approximately 20%, but increasing the frequency to 250 cps decreased the reaction to half. An isolated neuro-muscular frog specimen was more sensitive to EF than the same specimen connected to the central nervous system (CNS). /66

It was shown [Sazonova, 1960] that in studying the stimulating action of low-frequency EF on the neuro-muscular specimen, a temporary interval between effects of not less than 10 - 12 minutes must be observed in order to avoid aftereffects from the preceding stimulation.

If an EF (50 cps) with an intensity around 120 V/m is used, with which there is no actuating (causing contraction of the neuro-muscular specimen) action of the EF, a biological effect can be detected in the adjusting action, i.e., a change in the blocking of conductivity and chronaxy in the alteration section of the nerve (2 cm). As altering agents [Pudovkin, 1964] solutions were used with increased content of potassium and calcium ions, as well as a 0.5% solution of novocaine. It was discovered that the EF accelerates the development of a conductivity block by 20 - 25% and accelerates the chronaxy duration when potassium and novocaine ions are used. When calcium ions are used in the EF, weakening and even distortion of the action of this chemical factor on the nerves are observed. /67

The effect of the EF has also been successfully observed at the level of the entire organism [Rakhmanov et al., 1934]. A cage of mice was placed between plates and a current of about 90 kV actuated. Both the plates (disks with rounded edges) and the cage were placed in a funnel, in which the air was continuously replenished with a ventilator to avoid the possible effect of air ions. The session lasted 30 or 60 minutes. The number of sessions was 25.

After the testing ended, the mice were killed, and morphological studies were made of the internal organs. It was shown that the strong pulsating EF (gradient and frequency were not indicated) greatly affected the biological processes in the organism. There were changes in all systems. Most serious was the reaction of the reticular tissue: hyperplasia in the pulp and follicles of the spleen, perivascular infiltration in the liver and lungs, increased follicles and inflitration in the intestine, infiltrations in the skin. As in the complex with air ionization, some EF caused hyperplasia in reticular tissue, /68 swelling of epithelial structures, increased secretion, a reactive state in connecting tissue and degenerative effects in the muscles.

In spite of the persuasiveness of these facts, it is still assumed in physiotherapy that the biological action of air ions is the most important link in the electric complex. According to the theory of pulmonary electric exchange developed on the basis of this position, ionized air enters the lungs during inhalation, where electric charges are transmitted from the alveoli with colloid particles of the blood.

Later, it was discovered [Skorobogatova, 1963] that ionized air barely enters the lungs, and is deposited in the upper respiratory passages. The hypothesis has arisen that the physiological effect, when an organism is in an ionized gas medium, develops as a result of increased excitability of the receptors in the upper respiratory passages and skin adjoining the flow of air ions [Skorobogatova et al., 1964]. From the receptors, the subsequent transmission of developed signals proceeds by ordinary pathways along the nerves.

According to anatomical indications of these receptors, the flow of /69 afferentation under the effect of the EF proceeds mainly along sympathetic nerves (including the entire sympatho-adrenal system). The relation between the sympathetic and parasympathetic action on many functions is thus altered (respiration, cardiovascular system, metabolism, activity of internal organs, etc.).

On this basis, the problem of the biological effect of ionized air can be considered as only a part of the problem of the effect of EMF and EF on the organism. Their physiological action occurs mainly along a reflex pathway. The humoral component can now for a second time be drawn into the reaction [Skorobogatovaet et al., 1966].

This hypothesis of the reflex action of the EF on the organism does not reflect the entire complexity of the biological action of such a penetrating effect as that of low-frequency EMF. Results of works, emerging from the same laboratory, show that EF can directly affect the CNS [But, 1967]. It is important to note that the nervous system is one of the first to react to the EF, independently of how it is included in the reaction.

When guinea pigs were placed in an EF of industrial frequency with an /70
intensity of not more than 2 kV/cm, in the first 5 - 15 minutes the effect of strong motor anxiety was observed in the animals and an attempt to avoid that part of the cage where the intensity was greatest. Subsequently (three hours of exposure), the animals sat quietly, only sometimes making convulsive twitchings. Disturbances in respiration were noted, but no changes were discovered in the EKG or the blood pattern. In a number of cases the desensitizing effect of the EF took place, expressed in reduced anaphylactic shock and in a decrease in the number of lethal results [Novikov et al., 1966]. EF with frequencies of 20, 50, 200 cps, 5, 10 and 20 kc caused an equal degree of desensitization [Novikov, 1967].

By affecting mice with EF ($H \overset{\sim}{\sim} 1$ kV/cm) of various frequencies, it was possible to cause synchronized motor responses in the animals. The effect of the EF appeared in cumulative as well as in compensatory-adaptive reactions [Solov'yev, 1963].

When mice were placed in an EF (50 cps, 200 V/cm) accelerated mitosis was noted in cornea cells, and there was an increase in the number of cells

involved in mitosis. In tests on hydra, an intensification was established in the regeneration processes in the EF [Mamontov, 1965]. /71

These data from a few experimental works, although they have no direct relation to physiotherapy, indicate that EF have biological effects. This general position was the basis for developing a specific physiotherapeutic method which we shall describe in concluding this section.

Pursuing the idea of creating an improved device for air ionization, A. I. Konko [1960] concluded that the low-frequency EMF itself has a favorable effect on bronchial asthma patients. An instrument was thus created to provide low-frequency pulses. The low-frequency pulse (LFP) procedure is known as low-frequency pulse therapy, LFP-therapy. Sequence frequency varied from 25 to 40 cps. The pulse lasted 6 msec. The intensity in the electrode was 4.5 V, but only several mV reached the patient.

LFP-therapy has an antispastic affect in treating pneumosclerotic patients who also have bronchial spasms. No negative reactions were detected. Prolonged use of LFP-therapy had a good effect which was expressed in reduction of spasms, as well as cessation of short-windedness, coughing and asthma attacks [Kalinina et al., 1966]. /72

Experiments on rabbits established that low-frequency pulse EF affects blood pressure, respiration, and the electrical activity of the brain. In recording an electroencephalogram, slow high-amplitude waves were noted during the EF effect [Khvoles et al., 1962].

The results of many years of using LFP-therapy lead to the conclusion that the outlook is good for using pulse EF of low frequency and low intensity in physiotherapeutic practice [Konko, 1965]. These results represent an example of the development of new physiotherapeutic factors.

## Hygienic Evaluation of Electric Fields

The effect of EF on the human organism from a health aspect has still been little studied. As we have already indicated, in creating EF the biological effect was of primary importance. There have been two conferences on the problem: "Air Ionization in Work Hygiene" [1963, 1966]. From this broad /73
material, we shall only mention research on the level of ionization in airplane cabins. An increase in this level is noted in the flight process, which unfavorably affects the pilots' sensations. Artificially lowering the degree of air ionization to the natural level helped to normalize the functions of the organism, determined by pulse rate and respiration, as well as by the functional mobility of the optical analyzer [Ogleznev, 1966].

Recently, there have been discussions on the occupational-pathological evaluation of SEF in relation to the fact that in textile, woodworking, paper, and other factories, there is friction of materials with high dielectric properties. As a result of this friction, static electricity charges are formed and accumulated. The number of people working in a static electric field (SEF) increases as direct-current superhigh frequency electrotransmission lines (400 and 750 kV) are put in production.

The biological effect of SEF was noted in several experimental works. Reduction in respiration was noted in rabbits in 45% of cases, and it increased /74
in frequency in 22% of cases under the 15-minute action of SEF with an intensity of 82 V/m [Skorobogatova, 1966]. When electrical impulses from the vagus nerve of a cat under narcosis were recoded, a decrease was noted in the pulse activity of the inspirator neurons in the vagus nerve center under 10-minute action of SEF (100 V/m). It is assumed that SEF affects the functional state of both receptors (internal and external) and the nerve centers directly. It is important to note that the described effect is slight. Under all the experimental conditions, SEF had no effect on the electrocardiogram (EKG), arterial pressure, or respiration rate [But, 1966, 1967].

In studying the effect of SEF (50, 75 and 100 V/m) in one and two-hour exposure, changes in the gaseous exchange of mice could not be noted. SEF with these same parameters did not affect the survival time of the animals in hermetically sealed rooms. In twenty-four-hour exposure to SEF (50 V/m), an increased oxygen requirement was indicated by the mice in 5 - 7 days, but by 18 - 20 days, the recorded index was again equal with the index of the control /75
group of animals. This adaptation to EF resulted in increased resistance of the the mice to lethal radiation with ionizing radiations [Kartushenko, 1966].

It can be seen that the cited authors and several others [Vorob'yev, Ostryakov, 1968 et al.] are inclined to believe that the SEF has a biological effect, though it is weak. Other researchers were not able to detect the effect of SEF on the organism of man or animals.

By placing rabbits for six hours between plates on which a direct current with an intensity of 15 $\pm$ 1 kV was directed, the experimenters [Chebotareva et al., 1968] made broad dynamic studies of various indices. They determined the content of leucocytes, erythrocytes and hemoglobin in the blood, the amount of potassium and calcium in blood serum; rheobase and motor chronaxy of the muscles; the histological pattern of the internal organs; the content of lipides, glycogen and DNA; the activity of enzymes in tissue respiration (alkaline phosphatases, cytochromoxidases, ATP-ases). The indices were taken after six hours, 6, 12 and 45 days. Changes were not noted in the recorded indices. The authors suggest that the prolonged action of SEF could affect the organism.

However, in tests on rats some changes were noted in blood indices /76
(hemoglobin, number of erythrocytes), in pulse rate and respiration under the brief (15 - 60 minutes) action of SEF with an intensity from 195 tp 4000 V/cm [Portnov et al., 1968]. In a prolonged experiment (the effect of SEF with an intensity of 2000 V/m for four hours, six times a week, for a month and a half) no effect of SEF on the rats was observed.

In work with strong SEF, the EF and electric discharges may affect man [Krivova, 1968; Sazonova, Krivova, 1968 a, b; et al.]. It has been experimentally noted that the effect on test subjects of SEF (10 kV/cm) during 50 - 60 daily two-hour exposures does not cause changes in relation to the higher nervous system (EEG recording, conditioned reflexes, latent reaction time to electrical stimulation), the vegetative nervous system (body temperature, pulse rate, arterial pressure) or the blood system (leucocytic formula, amount of erythrocytes and hemoglobin, color index and the sedimentation rate (ROE).

Electric discharges, developing when a person is working in SEF (20 kV/m), had an unfavorable effect on the organism. An increase was noted in the /77
excitability of the cerebral cortex. The interchangeability of the hemispheres of the brain increased, which indicated its strenuous work. The variability of pulse and respiration increased sharply.

We must once more discuss the complex of effects when an organism is placed in an EF. In places where this complex is not divided — for example, in studying the sick rate pattern of people working within the sphere of influence of SEF [Portnov et al., 1968 b] — it is difficult to give a reason for the increase in the number of affected nerve and cardiovascular systems. In any case, the existence of the biological action of SEF cannot be considered proven.

The variable EF of industrial frequency is another matter. Medical examination of 35 electricians, working on electrotransmission lines with an intensity of 35, 110 and 220 kV, showed [Stroynova and Belyaeva, 1958] that no illness related to being in an EF developed. But when they were in the EF (220 kV), the people noticed feelings of heightened excitability and listlessness, chilliness, occasional pains in the skin, stirring of the hair and perspiration. In a 35 kV EF, these sensations were not evident, and in 110 kV EF they seldom developed. EF thus can cause slight disorders in relation to /78
the vegetative and central nervous system.

When the subjects were placed 2 m from a wire with an intensity of 65 kV, after 15 - 20 sessions of 0.5 - 3.0 hours, disturbances in their conditioned and unconditioned vascular reflexes were noted, recorded by the plethysmograph method. The subject's ability to work, determined by a correcting method, was reduced after being in the EF by 25 - 30%.

In animal tests it was established that an EF of 65 - 130 kV of industrial frequency in three-hour action on an object for 10 - 20 days caused weight loss in mice, and in rabbits a tendency toward slowed heat regulation and toward a slight increase in blood pressure. In the group of animals subjected to the EF effect, paralyses, narcoses and lowered resistance to infection were observed at a distant period [Stroykova and Belyaeva, 1958].

A disturbance in the balance of macroergic phosphorus compounds in muscular tissue was discovered under the action of an EF of 65 kV in mice after several three-minute exposures. Direct measurements were made of the rate at which the tail stiffened in dead control mice and those who were in the EF. The tail stiffened more quickly in the test mice [Stroykova and Belyayeva, 1957]. /79

In later studies [Sazonova, 1964, a, b] it was shown that persons working in strong EF of industrial frequency complained of listlessness, rapid fatigue, drowsiness, headaches, etc. Objective study of higher nervous activity by motor conditioned reflexes detected the development of an inhibiting process in the CNS as a protective reaction. Weakened functional stability was expressed in increased lability of the pulse and blood pressure, as well as in some disturbance in the heat-production and heat-transfer processes.

Under the experimental effect of EF of industrial frequency on subjects under a physical load, the development of an inhibitory process was detected in the CNS which was expressed in an increase in the latent period of the knee reflex and in an increase in the delay period of positive conditioned reflexes. The number of erroneous actions was also increased, and the

differentiated inhibition decreased. The noted weakening of the heartbeat and change in the tone of the vessels indicated the effect of EF on the vegetative nervous system [Sazonova, 1963]. /80

Tests on rabbits showed that the motor analyzer's ability to work is decreased in EF. The degree of fatigue depended on the intensity of the EF (300 or 1000 V/cm), the load on the muscle (32 or 82 g) and on the number of effects, i.e., on accumulated changes developing in repeated actions of the EF [Sazonova, 1964 a].

Injecting novocaine into the area near the sacral section of the spinal cord reduces the effect of the EF (100 kV/m) on the muscle's ability to work in the rabbit. This indicates that the action is manifested through the CNS. This conclusion was also corroborated in tests injecting a rabbit with aminazine and dibasol — substances which affect the function of the CNS [Sazonova, 1964 b].

Recently, an examination of 200 workers in substations with a variable current whose intensity was 220, 330 and 500 kV showed that they most often complain of fatigue, drowsiness, and headache. The primary form of neurodynamic disturbances was vegetative disfunction. Tachycardia and a tendency toward arterial hypertension were often noted. The hemoglobin content in the blood increased, and the ROE was accelerated [Revnova et al., 1968]. /81

Thus, many researchers agree in verifying the presence of the biological action of industrial frequency EF and the development of occupational pathology in persons working in EF. Attention must be paid to selecting safe permissible intensities and to the length of the EF effect. This work is complicated by the fact that, with the increased utilization of current intensities, the population is subjected to the effect of EF. Measurements of EF in populated areas, located alongside electrified railroad lines, have shown that the intensity reaches 300 V/m on footbridges 2000 V/m on the platform, and 2600 V/m on the tracks. These data point out the necessity of developing measures to protect the population from the effect of EF.

It must be noted that improved methods of physiological research make it possible to detect the biological action of EF when its intensity cannot be considered dangerous to human health. We shall discuss these data in the next section.

## The Ecological Value of Electric Fields /82

The effect on the organism of changes in natural electric fields (EF) caused by factors on the earth or in space, can point out the ecological value of this physical factor. Several authors [Biryukov, 1960] suggest that EF became an ecological factor for man with the broad introduction of electricity into industry and everyday life. In this section, however, we will only consider the biological effect of natural EF, or artificial EF of similar intensity.

Continuously recording atmospherically-produced pulsed EF for several years and comparing these data with the condition of patients suffering from hypertension and tuberculosis of the lungs has shown that in certain cases there is a direct relation between the intensity of EF and the number of complaints made by patients of various ailments [Konko et al., 1966].

These data were verified by many years of tests (1959-1965) on rabbits: healthy animals and those with experimental nephritic hypertension [Bogutskiy et al., 1968]. It was discovered that, when the electrical activity in the atmosphere increased, arterial pressure in the animals decreased; in the /83 rabbits with hypertension, this decrease was more pronounced. The results of this study are interesting in that they were conducted on animals (excluding any psychogenic effect) under natural conditions. However, the effect could have developed not from EF, but from some attendant factor. To eliminate these suspicions, it is necessary to test with artificial EF of similar intensity.

Another series of studies was aimed at the origin of heliobiological effects. In an astrophysical analysis of possible causes of these effects, it was suggested that EMF of a frequency on the order of several cps (less than 10 cps) might have a biological effect [Achkasova, Vladimirskiy, 1969].

Experiments were conducted to prove this supposition. Placing rabbits between condensor plates 1 $m^2$ in area and supplying these plates with a current from a low frequency generator with periodic oscillations (NGPK) — 3 m, the researchers [Volynskiy et al., 1969] created an EF with a frequency of 2 or 8 cps and an intensity of 0.5 - 1.0 V/m. The single effect lasted three hours. Repeated effects were conducted in 1 - 4 days. /84

In the EKG recording it was noted, that when the number of sessions was increased, the frequency of cardiac contractions decreased. Thus, after the first session this index was decreased by 12 $\pm$ 2.5; after the $5^{th}$ it decreased by 14 $\pm$ 1.6, and after the $10^{th}$ by 60 $\pm$ 8 beats per minute. A parallel progressive decrease in the voltage of several EKG waves was noted. After 6 - 10 sessions, ventricular extrasystole developed in individual rabbits.

In 3 - 5 week-old puppies, after the $3^{rd}$ session of the EF effect, heartbeat frequency increased to 15 - 25 beats per minute; wave voltage on the EKG increased.

In recording the EEG of rabbits, it was discovered that an EF of * cps causes a rapid increase in frequency of electric rhythms in the brain. The amplitude of biopotentials increased. The three-hour action of this EF caused a prolonged desynchronization reaction. Under the effect of a 2 cps EF, a widely-spaced rhythm of biopotentials was observed with an increase in their amplitudes.

In studying the blood of rabbits subjected to the systematic effect of EF, an increase in the number of leukocytes was noted and an increase in globulin

*Translator's Note: Illegible in foreign text.

protein fractions in the blood, while the albumin fraction content decreased. Under these conditions, the enzyme content in peripheral blood, alkaline phosphatases and cytochromoxidases decreased. Changes in the blood system /85
were maintained for a longer period of time after the EF ended than those in the CNS.

The data cited verify the possible effect of low-intensity, low-frequency EF on the organism. However, to reach a conclusion about the ecological value of these EF, it is necessary to study the effect of EF which are similar in intensity to natural EF and to make tests with shielding from any EF ("zero" EF effect); as yet this has not been done.

## Parameters of an EF Causing a Biological Effect

The opinion exists that an information effect is produced on the organism by signals of any energy whose intensity is between $10^{-2}$ and $10^{-12}$ $V/m^2$ with an optimum at $10^{-7}$ $V/m^2$ [Plekhanov et al., 1969].

This is a very abstract interpretation, as the concept of an "information effect" is not defined, and there is nothing to indicate the mechanism of this effect. However, these figures are taken from experimental works determining the sensitivity of specialized optical and auditory receptors in man; this opinion can be accepted as an initial working hypothesis.

According to the calculations of the authors cited, for a SEF, $E_{min}$ = $5.10^{-3}$ V/m, $E_{max}$ = $5.10^{8}$ and $E_{opt}$ = $1.5 \cdot 10^{6}$ V/m. As can be seen, all the researchers studying the biological effect of SEF worked within the limits /86
of these intensities, but nevertheless no effect was produced. In tests [Kholodov, 1966] no changes were seen in the EEG of rabbits under the effect of a SEF on the head of the animal with an intensity of $5 \cdot 10^{5}$ V/m, i.e., at an intensity close to optimum. Here we are not considering the reaction which develops at the moment the SEF is turned on or off, as for a variable SEF with a growth front from $10^{-3}$ to 10 sec, the calculated intensity values will be

$E_{min} = 8 \cdot 10^{-2} + 8$ V/m, $E_{max} = 8 \cdot 10 + 8 \cdot 10^{5}$ and $E_{opt} = 25 + 2.5 \cdot 10^{3}$ V/m. These figures agree with certain experimental data discussed earlier.

In analogy with the parameters of the electric component of the excited receptor rhythm, the authors suggest that the most pronounced effect on the organism would be produced by signals of optimum intensity, represented by a succession of millisecond exponential impulses with a frequency of 200 + 400 imp/sec.

In studying the EF as a conditioned stimulus, the authors successfully showed that the conditioned avoidance reflex of rats in the labyrinth develops primarily when the frequency of the succession of exponential impulses is /87
300 per second and when the intensity of the EF is 0.5 - 0.8 V/m. It is interesting that increasing the intensity 1 - 2 orders of magnitude from these values, without changing the remaining parameters of the EF, caused the effect to disappear. It would have followed to increase the intensity further to find out at what point the effect would appear again.

Marked worsening of the effect was observed when the frequency of impulses was changed in both directions at optimum intensity of the EF. At a frequency of 50 or 500 imp/sec, there was no longer any effect.

These data do not agree with results of tests on a neuro-muscular specimen [Petrov, 1953], where the most intensive reaction was observed at a frequency of 50 cps, and the effect was significantly reduced at frequencies of 50 and 250 cps. The noted discrepancy in the data of various researchers can be explained by a difference in the objects of study and different EF parameters.

Using square pulses of the EF as a conditioned signal at optimum frequency and intensity did not lead to the development of a conditioned avoidance /88
reaction in the rats. Analysis of the biological value of this EF parameter (impulse form) must be continued.

The influence of the EF duration and its localization on the ultimate biological effect has not been essentially analyzed as yet.

To determine the dependence of the biological effect on various EF parameters, long and tedious work is necessary to solve the questions of harmless, safe, and unsafe EF parameters [Korol'kova, 1962] and theoretical problems of electromagnetic biology.

## Characteristics of Biological Reactions to EF

In studying the biological effect of EF, naturalists most often employ those traditional research methods which were developed in studying specific adequate stimuli having specialized receptors. Critical intensity is considered to be that stimulus intensity which causes a sensation in man.

It can be assumed that EMF constitute a separate group of stimuli. Most /89
frequently, they are not sensed, although the reaction to EMF cannot at times be called weak (by way of illustration, imperceptible ionizing radiation can be lethal). Pronounced unconditioned reactions to EMF are not observed in animals. Conditioned reflexes to low-frequency EF are difficult to produce in man [Petrov, 1952].

It is assumed that external EMF, unlike adequate stimuli, primarily affect the hypothetical low-energy reaction system [Aladzhanov, 1962; Kholodov, 1966; Presman, 1968 et al.]. From this it can be concluded that methods studying physiological reactions under the effect of EMF on other, adequate stimuli will be more preferable, when the EMF is used as a corrigent stimulus and not as a triggering stimulus.

It has been shown that the biological effect of EMF is unusual and does not fit within the bounds of ordinary concepts about the thermal mechanism of the effect or of the response of living tissue to electric stimulation [Solov'yev, 1962].

A prolonged aftereffect was noted after the animal had been in an EF. /90
On this foundation, processes of adaptation to EF [Katrushenko, 1966] or processes of cumulation [Sazonova, 1963] could develop.

From this it can be concluded that considerable methodological work is necessary to recommend a suitable method of studying the biological effect of EF.

## The Biophysical Mechanism of EF Action

On the basis of published material on the biological effect of low-frequency EF (which is still of insignificant volume and nonuniform quality), it is difficult to reach a conclusion about the biophysical mechanism of the effect of this factor. In this material, several hypotheses about the possible mechanism of the effect of EF on a biological object were pointed out. The contradictory data about the frequency-selective character of the biological effect of EF has been noted. There are still no data about the relation of the biological effect to intensity and duration of EF action in a wide range of parameters. Therefore, we must refrain from discussing the hypothesis about the biophysical mechanism until the biological effect of the EF is described /91
in more detail from a quantitative point of view.

# IV. THE EFFECT OF MAGNETIC FIELDS ON THE HUMAN AND ANIMAL ORGANISM

A sceptical attitude toward the possibility of magnetic fields (MF) having an effect on biological objects was maintained until very recently, in spite of the positive results obtained in the 30's by physical therapist Shcherbak and his associates, biophysicist Lebedev in coauthorship with Kam and Yaure, 1926, pharmacologist Kravkov, and botanist Savostin [1928-1937].

We must mention the pamphlet of Dr. I. L. Baumgol'ts, published in 1936, in which he maintained, on the basis of the "position percussion phenomenon",

that a geomagnetic field (GMF) affects the human organism. The essence of the "phenomenon" is that the penetration through various tissues of man by sound depended on the geographic orientation of the organism.

A significant contribution to the development of magnetic biology was made by the Perm researchers headed by physicist V. I. Karmilov, physiologist M. R. Mogendovich, and clinicist A. S. Seleznev. The majority of publications /92
appeared at the end of the 40's and among them was the first collection of works on magnetobiology in the world, "The biological and medical effect of the magnetic field and strictly-periodic vibration," published in 1948.

The main flow of Russian, as well as foreign, works on magnetobiology occurred in the 60's. In the last ten years, approximately 450 have appeared and this number increases with each year. During the 20$^{th}$ century we have had about 500 Russian publications on magnetobiology, which is a little more than half of the works in all languages known to us. It is significant that about half of these works have appeared in the last three years.

Of course all these works are not of equivalent value. The majority of them are in the form of theses, from which it is difficult to extract a detailed description of methods and results of the experiments. However, the large number of theses indicates the rapid development of this field of knowledge. In recent years, summarizing articles have appeared [Kholodov, 1965; Novitskiy, 1967, 1968; Vilenchik, 1967; Dernov et al., 1968; Toroptsev, 1968 et al.] and two monographs [kholodov, 1966; Presman, 1968] where questions /93
on magnetobiology are discussed in sufficient detail.

In the last decade, unlike the previous years, a large amount of information has been accumulated on the biological effect of magnetic fields MF. We shall attempt to review the basic trends of this research, although a great lack of coordination in the methodology of magnetic action and in the ways of analyzing it oblique us to consider this as a purely preliminary attempt.

We shall consider the effect of artificial MF, which exceed the GMF, on various representatives of the animal kingdom, on various systems of the organism, and on the cellular level of biological organization. The possibility of a biological effect from changes in the GMF merits separate discussions.

## The Biological Effect of Artificial MF

This heading includes the majority of magnetic-biological studies which used MF with an intensity from several tens to several thousand oersteds (in some cases to 140 kOe) with exposure from several seconds to several days. The objects of study were most diverse. Most often the purpose was to verify biological action of a MF.

### The Effect of MF on Animals. /94

Can we now, on the basis of separate studies, answer the question, which animals react to MF?

Although no systematic studies have yet been made on the comparative magnetic sensitivity of animals at various levels of organization, separate publications show that representatives of the majority of the animal species have a reaction to artificial MF (Table 1). In the table sources of the analyzed information are not cited. Qualitative characteristics of MF (uniformity, direction of lines of force, etc.), duration of the action, and a detailed description of the biological effect are beyond the scope of the table.

Data in the table show that even the simplest single-celled animals are able to react to external artificial MF, changing their behavior and their metabolism. This forces one to assume that primary magentobiological effects can develop at the cellular level in multi-celled animals.

TABLE 1. THE EFFECT OF ARTIFICIAL MAGNETIC FIELDS ON VARIOUS VITAL INDICES FOR INDIVIDUAL REPRESENTATIVES OF THE ANIMAL KINGDOM.

/96

| Species | Class | Representative | Intensity of the MF in oersteds | Recorded biological index |
|---|---|---|---|---|
| Protozoa | | Paramecia | 100-8000 | Orientation, behavior, motor activity, reproduction, increase in metabolism |
| Worms | | Planarians | 100-1000 | Orientation, behavior |
| Arthropoda | Crustaceans | River crayfish | 500-2000 | Bioelectric activity |
| | Insects | Wood louse, fly, cockroach, cockchafer, termites, etc. | 10-140,000 | Orientation, behavior, motor activity, bioelectric activity, reproduction, genetic effect |
| Mollusks | | Helix nassarius, chiton, vineyard snails, etc. | 4-8000 | Orientation, motor activity, bioelectrical activity |
| Echinodermata | | Sea urchin | 1000-140,000 | Development |
| Chordata | Fish | Mormyrus, carp, stickleback, trout, etc. | 20-10,000 | Behavior, motor activity, development |
| | Amphibians | Frogs | 100-10,000 | Sensitivity, development, cardiac activity |
| | Reptiles | Turtles | 10,000 | Cardiac activity |
| | Birds | Pigeon, chicken, bullfinch, etc. | 200-1000 | Behavior, motor activity, EEG, development, etc. |
| | Mammals | Mice, rats, guinea pig, rabbit, cat, dog, monkey, man | 100-140,000 | Behavior, development, growth, EEG, etc. |

We do not know of any publications which analyze the effect of MF on /95
sponges or Coelenterata. At the same time, information on MF reactions in representatives of the Coelenterata species in which a nervous system first appears would clarify the nature of the reactions of a milti-celled organism as compared to the single-celled ones.

Representatives of flat worms — planarians — have clear behavioral reactions to MF; this has been stated by several unrelated groups of researchers.

Annelida have evidently not been an object of magnetobiological research, but the next species — arthropoda — have been studied with representatives of the crustacea class. The insect class was very intensively /97
studied in various MF. Changes in the electric activity of neurons (mostly inhibition) were noted in the river crayfish and cockroach. Noted in other insect representatives were orientation to the GMF, changes in motor activity in the GMF and artificial MF, changes in development, genetic effects and other after-effects of MF action.

Mollusks were included in the sphere of magnetobiological studies, because ferromagnetic substances were discovered in some of their shells and radulae. However, this hardly explains their orientation to the GMF, or even more the change in the activity of an isolated heart in an artificial MF.

The only representatives of Echinodermata in a MF were fertilized sea urchin eggs. Their development was often retarded after the action.

Of chordata species, only representatives of the vertebrate subphylum were studied intensively. Of these, first place is held by the mammal class, then birds, fish, amphibians and reptiles. The heightened interest in mammals is explained by their evolutionary similarity to man. Birds and /98
fish were studied primarily in relation to the geomagnetic theory of the

orientation of these animals. Amphibians and reptiles were studied as a convenient experimental object.

Thus, various representatives of the animal kingdom display varied reactions to MF. Disregarding certain omissions which distinguish our table from a systematic table of zoology, we can say that all animals react to MF. It must be mentioned that plants and microbes also react to MF, and therefore the entire biosphere can theoretically react to MF.

## The Effect of Artificial MF on the Human Organism

It is possible that MF will in the future be widely used for practical purposes in raising live stock and plant growing. For the time being, most important are practical questions related to the hygienic evaluation of MF produced in industry and those related to magnetic therapy.

### Clinical Hygiene Data on the Effect of MF in Industry /99

Isolated hygienic studies of the possible effect of MF in industry were conducted in England and Germany as far back as the 1920's. However, the results of these works were indefinite.

Since 1961, a group of doctors in the F. F. Erisman Scientific Research Institute of Hygiene in Moscow, under the leadership of A. M. Vyalov [1964-1969], have been studying the effect of diffused MF in industrial-laboratory conditions. There were 1500 persons under observation by the clinicists. About 60% of the people were studied 2 - 5 times.

In those subjected to the prolonged effect of MF (their hands were in a field with an intensity of 350-3500 Oe, and the head — in no more than 150-250 Oe) for 20 - 60% of the working time, deviations were primarily noted in the nervous and cardiovascular systems. Neurological deviations were characterized by headaches (in the second half of the day and after work),

pains in the region of the heart, fatigue, dizziness, decreased and unsteady appetite, insomnia, increased sweating, sensations of itching and burning in the hands.

Studying the EEG of these people revealed a tendency toward predominance /100
of the inhibitory process in the brain. Slow waves and alpha-rhythm spindles were noted at rest and in light tests.

Otoneurological studies most often indicated the central origin of the inhibition of this apparatus (oculovestibular disturbances).

19 - 32% of the examinees complained of unpleasant sensations in the region of the heart. Objectively, in 11 - 43% of the cases a change in the sonorous nature of heart tone was detected. A reduction in heart-beat frequency (bradycardia) was noted in 5 - 43% of the examinees. The more intensive the MF was in industry, the more often bradycardia was encountered.

In 34 - 43% of the people, a positive decrease in maximum arterial pressure of 10 - 18 mm was detected. It was interesting that the rate of hypertension in workers in MF was lower than in the Soviet Union as a whole. Changes in the electrocardiogram were insignificant.

Deviations were also encountered in relation to certain biochemical indices and the morphological condition of peripheral blood. In persons /101
working in magnetic fields, an increase was observed in the gammaglobulin content in the blood and a decrease in the content of nucleonic acids and the enzyme oxidase. The morphological condition of the blood is characterized by a decreased number of leucocytes and reduced erythrocyte accumulation rate (ROE). Studies of the blood indicate that MF stimulates the reticuloendothelial system.

Clinical observations show that the majority of changes which occur in the human organism under the effect of MF have a temporary functional character

if persistent pathological damage to the hands is not considered.

In the hands of 36 - 41% of the workers, distinctive vascular-vegetative disturbances were discovered and increased sweating on the surfaces of the palms. The hands were warm to the touch, as if they had just been taken out of hot water. Deviations from normal were noted when the temperature was taken. The skin and the hypodermic tissue were often somewhat edematous. Sometimes shedding of the skin was observed on the palms, and the almost complete absence of any pattern. Some decrease in mobility was noted in inter-phalange articulation. Volitional sensitivity was often decreased. /102

A. Ya. Shiyanevskiy [1966] suggests that these local vegetative-trophic disorders be considered as decisive factors in diagnosing "magnetic sickness." It is probably too early to assign these poorly studied syndromes to a separate "sickness".

This disease is called vaso-vegetative polyneuritis. It is believed that, when workers have this disease, they must temporarily avoid working in the MF and pursue a course of medical treatment. It is best to start with local vibration massage, ion-galvanization with calcium and a water bath with a decreasing temperature for the hands. Agents for decreasing swelling are shown which thicken vascular walls (calcium, vicasol, citrine, and rutin). It is advisable to combine local treatment with general treatment, i.e., to use group B and C vitamins, sedatives and other general tonic agents (injection of duplex, mesatone, etc).

Today, therefore, MF is considered as an unfavorable factor in the industrial environment. Further increase of its intensity in industry will necessitate occupational-pathological evaluations. What are the safe permissible intensities of MF in industry? /103

A. M. Vyalov suggests that MF intensity in industrial conditions at the hand level not exceed 700 Oe at a gradient of 10 - 20 Oe/cm, and at

the remaining levels of the body — 300 Oe at a gradient of 5 - 20 Oe/cm.

The following diseases whould medically contraindicate work with MF: organic heart and vascular diseases, stenocardia, arterial hypotension and hypertension, pronounced endocrine diseases, organic damage to the central and peripheral nervous system, especially vaso-vegetative polyneuritis, neuroses and neurosis-like conditions, vegetative-vascular malfunction.

Comparing the above with the results of experimental research on the effect of MF on animals, we can see much in common in the conclusions. A MF affects the nervous and cardiovascular system to the greatest degree, as well as the blood. Hygienists suggest that MF first of all cause the first stage of the parabiosis described by N. Ye. Vvendenskiy (change in lability) /104
in the vegetative nervous system. Although it is concluded that these changes do not extend far beyond the limits of physiological shifts, it is evident that the tendency of the functional state of the organism to change is the same as in the action of more physiologically-strong stimuli, and electromagnetic fields of the UHF and SHF range.

As far as suggesting the possibility of creating an MF to protect spacecraft from radiation forces, on the basis of the cited information it is still impossible to construct a picture of the possible action of these MF on astronauts. Further studies are necessary both on man and on other primates.

## The Therapeutic and Diagnostic Use of MF in Clinical Medicine

It has now become an established tradition to speak of magnetotherapy in a slighting tone, as in many reports on this problem doubtful information is cited. We have all the same decided to note certain modern magnetotherapy data which contradict basic tendencies of magnetobiology very little.

First of all we must mention the Perm physicians who used a permanent /105
magnetic field (PMF) to treat various diseases. A favorable result was achieved in pains after the amputation of an extremity, in causalgia and nefritis, in the clinical treatment of internal diseases and in cardio-vascular diseases. In some Perm hospitals a MF is now used as an anesthetic and resolution agent, useful in cicatrizing wounds and ulcers [A. A. Tyuryayeva, 1965-1969].

There is a report that in damage to peripheral vessels, (primarily arteriosclerotic in early stages of development), a MF has a medical effect like that of other physical factors [Kordyukov, 1969; Murav'yev, 1969 et al.].

In patients with the $1^{st}$ stage hypertension, magnetic bracelets had a positive effect. Subjective symptoms of the disease disappeared; arterial pressure was normalized. The effect of the magnet was less pronounced at the $2^{nd}$ stage of hypertension. Placing the bracelet 30 minutes before sleep on the occipital and temporal regions of the head caused pains in these areas to end quickly [Andreyev, 1966, 1969].

A favorable effect of wearing magnetic bracelets was noted in some /106
patients with diseases of the nervous and cardio-vascular system. Improvement was expressed mainly in a weakening or disappearance of subjective symptoms. In only isolated individuals was a temporary slight improvement in certain objective indices recorded. As one of the reasons for improvement in the way the patients felt, according to N. V. Tyagina [1966], we must recognize the possibility of psychotherapeutic effect as well as the effect of a weak magnetic field in the form of a non-specific stimulus.

According to the data of the Central Scientific-Research Institute of Health Resorts and Physiotherapy, in observing dozens of patients suffering from hypertension, an improvement in subjective indices was noted in only a third (reduction of headaches, improved sleeping, increased ability to work).

Objective indices (blood pressure, lecithin-cholinosterol exchange, electrocardiography) did not change as a rule. Therefore, there was a psychotherapeutic effect [Obrosov, 1966].

Thus, research of three different Soviet medical institutions, conducted independently of each other, produced similar results. In the initial /107
stages of hypertension, magnetic bracelets made some patients feel better.

We will not enumerate here the many studies on the effect of a MF on the development of implanted tumors in experimental animals [Ukolova et al., 1960-1969 et al.].

But as far as the ultimate end of each experimental study of tumors — finding means to treat man — the most valuable works are those studying not implanted tumors, but induced (caused by cancerogenic substances) and spontaneous (from unknown reasons) tumors. Under the effect of MF, M. A. Ukolova inhibited the growth of tumors in rats; the tumors were caused by injecting a cancerogen — 3.4 benpyrene. This shows the effectiveness of magnetotherapy in induced tumors.

In 1968 the report of S. A. Proskulyakov appeared which noted the favorable effect of MF on tumors of the larynx.

However, the empirical use of MF in medical oncological practice, as in the case of the magnetic bracelets, cannot produce the desired result /108
until a general theory is developed about the effect of MF on healthy and diseased organisms.

The diagnostic value of MF is also first encountered in the works of the Perm physicians, who noted a change in ROE rate in MF in tuberculosis patients [Goncharova, 1948]. Similar results have also been obtained in recent years in studying ROE in MF in patients with tuberculosis of the lungs [Golovatskiy, 1964, 1968], hypertension [Neiman et al., 1966] and in the pathology of pregnancy [Komar, 1969].

There is an indication of the diagnostic value of the increased number of leucocyte nuclei in a PMF (H $\sim$ 50 Oe) which turn green in cytoluminescent analysis [Sosunov, 1963, 1969]. This increase corresponds to severe pathological processes in the skin [Kozak and Zagoruyko, 1966], infectious [Kozak and Parkulab, 1966], gynecological [Piksina, 1969] and oncological diseases [Zbirak and Keyvan, 1966], as well as in tuberculosis of the lungs [Golovatskiy, 1964, 1968] and goiter [Mileshina, 1969].

A magnetochemical test was also suggested to determine the stability /109
of protein complexes in blood serum [Sel'kov, 1963]. The microscopic structure of the serum in a MF changes in relation to the development and character of the disease in the person from whom the blood was taken. Similar observations have been verified [Charnaya, 1966, 1967], and it has been shown by the electrophoretic method that a shift in blood serum is observed toward the globulin fractions.

Finally, determining the activity of enzymes in the blood and urine in a MF can also serve as a diagnostic indicator. Thus, aldolase and alkaline phosphatase in the blood of patients with rheumatism and stomach ulcers decrease activity in a PMF [Dubova, 1969]. In rheumatism and severe damage to coronary blood circulation a decrease in the activity of fibrinase is noted in a PMF [Grinevskaya et al., 1969]. Diastase in the urine also changes its activity in a PMF in certain diseases in man [Dubova, 1969].

It is evident that in the majority of cases changes in various components of the blood system in MF may be used as a diagnostic indication. We shall discuss reactions of this sytem to the effect of MF, but now it is important /110
to note that the suggested diagnostic indications are based on the results of experimental methods, and therefore are very valuable in comparison with purely therapeutic studies.

## Experimental Data on the Effect of MF on the Human Organism

Usually man perceives any stimulus in the form of a sensation. It is believed that a PMF has no sensory effect. In any case, in questionnaires circulated in recent years to the directors of many physics laboratories in the USA, the physicists answered that they experience no sensations when they are in a PMF with an intensity up to 20,000 Oe for several minutes. However, special research by physicians has shown that under certain conditions a MF can cause sensations.

Many physicians of the last century, including such authorities as Botkin and Sharko, noted that in certain patients a magnet could: (1) cause itching at the site of the effect, shivering, aches or pains, (2) restore disturbed sensitivity of the skin and retina or "transfer" anesthesia from /111 the affected half of the body to the healthy half, (3) obliterate or reveal paralyses, convulsions, and contractions, (4) soothe pains of various origins or cause passing pains, (5) cause general weakness, headache and drowsiness.

Several of these reactions were also noted by the Perm physicians [Karmilov, 1948] in using PMF.

Most reliable is the fact discovered by D. Arsonval [1895] of a subjective sensation of flashes of light (phosphene) when the head of a person was subjected to a PMF with a frequency of 10-100 cps. As a result of many studies, it has been established that the optimum freuqency of stimulation was 20-30 cps. An effect was observed at 400 Oe. When the intensity was increased to 800 Oe, the duration of the sensation increased from 1 sec to 20 sec. The phosphene sensation also developed when the PMF was switched on and off; in the latter case, the sensation was more intense. However, the magnetic-phosphene was often explained by the development of emf induction, stimulating receptor cells in the retina (rods and cones), and was therefore not connected with other magnetic-biological effects. In later works, some

researchers did not agree with this explanation, as by preliminary calculation /112
induction emf is 3 - 4 orders of magnitude less than the intensity which causes the electrophosphene [Liberman, 1958] and the value of the magnetic phosphene depends on the duration of the MF effect [Solov'yev, 1963].

In the light of these data, the theory of magnetic-phosphenes cannot be considered complete. Probably much could be learned from experiments with the effect of MF on the isolated retina of animals.

Besides phosphenes, other changes were also noted in the activity of the optical analyzer under the effect of a MF. In a PMF stable vision was decreased in man [Mogendovich and Skachedub, 1957]. A permanent magnet, applied to the back of the head of the subject, altered visual images suggested under hypnosis [Vasil'ev, 1921] and intensified visual hallucinations caused by mescaline intoxication [Perikhanyants et al., 1947].

We have already noted that damage to the skin of the hands develops in persons subjected to the effect of MF under industrial conditions [Vyalov, 1964-1969].

The data cited above show that, although the MF does not cause special /113
"magnetic" sensations in man, this stimulus breaks into the sense sphere mostly through the visual and skin analyzer. In the latter case, it has been proven that a MF affects the peripheral receptor structures, i.e., the afferent part of the three-member reflex arc. When the sensation develops in the visual analyzer, the MF could affect both the receptor and the central part of the reflex arc.

It is reasonable to assume that a MF can also affect the activity of other analyzers, although this kind of research is clearly inadequate.

The effect of PMF on motor activity in man was studied in patients during hypnosis and in healthy individuals in a wakeful state. Applying a

magnet (400 Oe) to the occipital region of the patient sometimes weakened hypnotic catalepsy. The arm stretched out in a cataleptic pose began slowly to fall. In the healthy subjects, the PMF (1200 Oe) reduced the average frequency of waves in the tremogram of the extended arm [Aminev, 1965, 1966].

The action of a MF (H $\sim$ 1000 Oe) on the back of the head of a healthy person led to a decrease in skin sensitivity on the arm when it was stimulated with an electric current [Nikolayev, 1960].

When the hand of the subject was subjected to the effect of a MF with /114
an intensity from 100 to 7500 Oe for 15 or 60 minutes, a decrease was noted in the sensitivity of the skin of the hand and an increase in its temperature, as well as an increase in the calcium content of the blood and a decrease in sodium and chlorine. The pulse was reduced [Vyalov, 1969]. A decrease in the number of heart contractions of approximately 5% was detected when the head of the person was subjected to a MF with an intensity of about 1 Oe [Bil'dyukevich et al., 1969].

Therefore, existing experimental and therapeutic data indicate that various systems of the organism react to MF in different ways. However, the comparative sensitivity of these systems to MF can only be evaluated at the present time according to the vast material obtained from experimental animals.

## The Effect of MF on Various Systems of the Organism of Vertebrate Animals

In the reactions of an organism to any external influence, the regulatory mechanisms carried out by the nervous and humoral systems are very important.

### The Effect of MF on the Nervous System /115

Some researchers of the last century suggested that the effect of MF on the organism is realized only through the nervous system. Therefore,

modern researchers have studied intensively the effect of MF on the nervous system [Vasil'yev, 1921; Erdlan, 1955; Kholodov, 1959; 1966; Aminev, 1965; Druz', 1966]. Reactions of the whole organism were discovered in the form of a change in motor activity (most often an increase), inhibition of developed conditioned reflexes, reduced sensitivity to various stimuli, and reduced possibility of developing conditioned reflexes to MF, which were less permanent in comparison with conditioned reflexes to ordinary stimuli (light, sound).

Electrophysiological methods were used to study the reaction of the nervous system to MF at the system level. Changes in EEG, mostly in the form of an increase in the number of slow waves and spindle-shaped fluctuations, were observed in reptiles [R. Bekker, 1963], in pigeons [Gualtirotti, 1963], in rabbits [Luk'yanova, 1967; Chizhenkova, 1966], in monkeys [Nepton and Beisher, 1966] and in man [Vyalov, 1967].

Electrophysiological and histological methods were used to study the /116
reactions of the CNS to MF at the cellular level. The MF most often retarded the pulse activity frequency of neurons in various sections of the brain of a rabbit [Luk'yanova, 1967], in the abdominal nerve chain [Luk'yanova, 1966] and extension receptor of river crayfish [Kogan et al., 1968] and in the sub-glottal ganglion of a cockroach [Sittler, 1966]. Increased affinity to silver after the effect of the MF was manifested by the glial cells in the brain of mammals [Aleksandrovskaya and Kholodov, 1966].

Experiments with neuronal isolation of individual nerve structures have shown that the MF affects a section of the brain deprived of nerve connections with all sense organs even more strongly than the same intact section . Therefore, the MF, having a penetrating effect, affects the brain directly, eluding the sense organs.

Reactions to MF of sections of the brain of a rabbit were arranged in the following descending order according to the intensity of the EEG:

hypothalamus, sensorimotor cortex, visual cortex, specific thalamus nuclei, non-specific thalamus nuclei, hippocampus and reticular formation of the mid-brain. The proximity of the hypothalamus to the humoral regulation center, /117
the pituitary gland, causes one to assume that the endocrine system is not indifferent to the effect of MF.

## The Effect of MF on the Endocrine System

The hypothesis has been expressed that the MF, acting through the nervous system on the anterior pituitary gland, increases the production of the adrenocorticotrophic hormone and thus leads to atrophy or complete disappearance of the fascicular zone of adrenals in mice [Sumezhi et al., 1966]. Hypersecretion of the thyroid gland was noted under the effect of MF [Ukolova and Kvakina, 1969] and morphologically-determined disorders of the sex glands, especially the testicles [Toroptsev, 1968]. Thus, the endocrine system assumes an active part in an organism's reaction to a MF.

## The Effect of MF on the Blood Circulation System

The effect of the MF on the vascular system is realized first of all through the nervous system, as even after brief action dilation of blood vessels was noted in many organs in the pathomorphological study of animals [Karmilov, 1948; Toroptsev, 1968]. In persons subjected to the effect of MF in industry, bradycardia was noted [Vyalov, 1967]. In monkeys, squirrel /118
monkeys, pulse was reduced and the amplitude of the T wave in the EKG increased in a strong MF [Nepton and Beisher, 1966].

However, the action of MF on the vascular system can also be realized directly, at least passing by the central nervous system. This is illustrated by the results of tests on the effect of MF on the isolated heart of a vineyard snail [Khalazonitis and Arvanitaki, 1965], a frog [Karmilov, 1948; Osipov, 1966; Shishlo, 1969] and a turtle [Young and Goffman, 1965]. MF also affected the vascular system of the isolated ear of a rabbit [Kravkov, 1924; Lazarev et al., 1926].

## The Effect of MF on the Blood System

Blood has been studied intensively under the effect of MF on it in the test tube, and under the effect of a MF on the entire organism. Reactions were observed in relation to all its component parts. Protein fractions in serum reacted to the MF [Sel'kov, 1963; Chernaya, 1966; Vyalov, 1967] as well as the enzymes which exist in it [Belokon' et al., 1966]. Under the effect of an MF, the number of red blood corpuscles increased and the /119
erythrocyte accumulation reaction was slowed down [Mogendovich et al., 1948]. The number of leucocytes and their phagocytic activity was altered [Sherstneva, 1951]. Coaguability of the blood was changed, which is possibly related to changes in thrombocyte function [Damilin, 1957]. It is important to note that changes in relation to the blood system could also develop in the direct action of MF on the blood and in its indirect action through the CNS.

## The Effect of MF on the Respiratory System

The respiratory system altered its activity under the effect of MF at various levels. It has already been mentioned that red blood corpuscles reacted to the MF. Dyspnea and emphysema were noted in lung tissues. An increase in mucopolysaccharide substances was observed in the lungs and almost complete loss of tinctorial properties of the agyric (sic) substance [Gorshenina, 1965]. General oxygen consumption by a mouse was decreased in MF [Tishan'kin, 1950; Shishlo, 1966].

## The Effect of MF on the Digestive and Excretory System

The effect of MF on the digestive system has been comparatively poorly studied. A reduction in the weight of the liver was noted in mice after they were in MF [Barnoti, 1960]. Changes determined morphologically were found not only in the digestive, but also in the excretory system. Usually weak /120
destructive changes were found in the epithelium of kidney and liver ducts.

However, the increased function of these organs, by the injection into the organism of choleretics and diuretics, intensified the magnetobiological effects. In the liver, changes appeared in cupriferous cells in the form of hypertrophy and vacuolization of the nuclei. In the kidneys, the epithelial part of the nephron was more sensitive [Rassadin, 1966]. Changes were noted in the nerve elements of the gastro-intestinal tract in the form of increased argentophilization [Ryzhov, 1968].

## The Effect of MF on the Integumentary System

In the nerve elements of the integumentary system, in the skin, reactive changes were observed in guinea pigs under the effect of a MF [Ryzhov, 1969]. People who often placed their hands in strong MF during work developed damage in the skin integument, and there were changes in the sweat-producing function [Shiyanevskiy, 1966; Vyalov, 1967]. The question is raised about peripheral vegetative-tropic damage to the skin of the upper extremities in humans.

## The Effect of MF on the Muscular System

The isolated muscular system of vertebrate animals has been studied comparatively rarely in magnetic-biological experiments. However, a neuro- /121
muscular frog specimen has often been placed in various MF. The effect obtained was usually explained by the effect of the MF on the nerve. However, the local effect of a MF on a single nerve fiber did not affect the function of the neuro-muscular specimen [Liberman et al., 1959]. Possibly the reaction of the neuro-muscular specimen to a PMF, recorded by several researchers, [Aminev, 1965; Pustovoit et al., 1968] is also accomplished by the participation of muscular tissue.

## The Effect of MF on Sense Organs

Although MF can affect the CNS even in the absence of receptors, this does not mean that sense organs do not react to MF. We have already mentioned

the sensory effect of MF. MF not causing specific "magnetic" sensations can penetrate into the sphere of the senses by the nonspecific stimulation of certain receptors.

Morphological methods were also used to study the reaction of the organ of sight to MF. Hyperemia of the vessels, edema of the cornea, and a /122
decrease in its sensitivity were noted as well as vacuolization of its epithelium. Also noted were disorders in lymph circulation in the ciliary body, hydropic changes in the epithelium of the anterior capsule of the crystalline lens, vacuolization of its cortical layer and necrobiosis of individual ganglion cells in the retina [Teplyakova, 1967].

## Comparative Magnetic-Sensitivity of Various Systems of the Organism

Summing up this brief review of information about reactions of the organism of vertebrate animals to artificial MF, one can say that physiological and morphological data both indicate participation of all systems of the organism in these reactions. We shall note that pathological changes under the effect of MF are not catastrophic in the majority of cases; this might characterize it as a relatively weak stimulus.

On the basis of this review, it is difficult to say which system of the organism is the most sensitive to MF, as their reactions were evaluated only qualitatively by various methods and under the general effect of the MF on the organism. However, it would appear that the nervous and vascular systems are most reactive.

A study exists where the magnetic-sensitivity of various organs was /123
evaluated quantitatively by the same method. Table 2 gives values of the hydration capacity of various tissues in white mice under the effect of various MF; these were taken from the dissertation of V. A. Druzya [1966].

It must be taken into account that the author did not obtain these results simultaneously (possible seasonal relationship of magneto-biological effects) and disregarded the varying survival ability of different tissues.

Analyzing data in the entire table, one can see that changes under the influence of a MF most often develop in the small intestine, then the brain and other organs, and in last place is the liver. Under the effect of a PMF of various intensity for one minute, the brain is first, both in terms of frequency of changes which develop and in sensitivity to the PMF. However, the author believes the brain is a stable structure, as the level of changes in maximum hydration capacity in a MF was insignificant in comparison with other organs.

When a PMF (200 Oe) was directed on tissue from sparrows, a decrease was noted in the water-absorbing capacity of the heart by 21.5%, of the pectoral muscles — by 10%, and of the brain — by 3.5% [Madiyevskiy and Volosh, 1969]. /124

Therefore, a MF causes paranecrotic reactions in various tissues and systems of vertebrate animals.

Morphological studies of various organs in guinea pigs which spent several hours in a MF showed that the "shocked" organs, i.e., those most damaged, are the testes. Ovaries were damaged to a lesser degree, which indicates a sexual difference in reactions to the MF and great "magnetic damage" to males. Damage was detected in the lungs, liver, kidneys, in eye structures and in CNS [Toroptsev, 1968]. /126

Thus, the sequence of organs in order of their reactions to the MF varies according to the data of different researchers. These apparent contradictions can be reconciled if one considers that magnetic-sensitivity and magnetic-damage are determined by different methods, and the organ under study is characterized from different aspects. The brain seems to be very

TABLE 2. CHANGE IN THE MAXIMUM HYDRATION ABILITY OF DIFFERENT TISSUES OF WHITE RATS DURING THE INTERACTION OF DIFFERENT MAGNETIC FIELDS (CONTROL INDICES WERE 100%)

Object

| Tissues studied | Nature of MF | PMF | | VMF 50 cps | PMF | | | | | VMF *3 cps | | | | VMF 50 cps | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Exposure | 1 min | 20 min | 20 min | 1 min | | | | | 1 min | | | | 1 min | | |
| | Intensity | 8 kOe | 8 k/Oe | 0.5 k/Oe | 1 k/Oe | 2 k/Oe | 6 k/Oe | 8 k/Oe | 20 k/Oe | 1 k/Oe | 2 k/Oe | 6 k/Oe | 8 k/Oe | 0.5 k/Oe | 1 k/Oe | 2 k/Oe |
| | Liver | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 86 | 100 | 117 | 100 | 100 | 100 | 100 | 81 |
| | Brain | 100 | 134.8 | 100 | 107 | 127 | 89 | 91 | 80 | 100 | 100 | 100 | 76.2 | 121 | 100 | 85 |
| | Kidney | 100 | 100 | 89.5 | 100 | 100 | 107 | 92 | 92 | 118.5 | 96 | 100 | 100 | 100 | 100 | 94 |
| | Muscles | 100 | 127.3 | 131 | 100 | 100 | 100 | 95 | 63 | 100 | 100 | 100 | 89 | 120 | 100 | 89 |
| | Spleen | 100 | 100 | 134.5 | 100 | 114 | 100 | 100 | 100 | 100 | 100 | 83 | 62 | 100 | 100 | 69 |
| | Testes | 100 | 100 | 158 | 150 | 100 | 100 | 100 | 53.5 | 100 | 100 | 100 | 100 | 100 | 100 | 70 |
| | Small intestine | 53.8 | 62.9 | 65.9 | 100 | 100 | 114 | 88 | 84.6 | 100 | 121 | 100 | 57 | 131.8 | 100 | 79 |
| | Heart | 100 | 100 | 100 | 100 | 79 | 77 | 85 | 70 | 100 | 100 | 100 | 80 | 91 | 100 | 76 |

*VMF designates variable magnetic field.

sensitive, but at the same time a quite stable organ. A similar conclusion was reached by radiobiologists comparing physiological and morphological data on the effect of ionizing radiation on the CNS [Livanov, 1962; Gorizontov et al. 1966].

It is important to note that the accumulation of morphological changes which develop under the influence of a MF on the integral organism indicates the specific nature of the pathological-anatomical pattern [Toroptsev, 1968]. /127 At the same time, the magnetic-sensitivity of various organs has a nonspecific character, i.e., under the influence of other altering factors, tissues reacted in the same way and in the very same sequence as under the influence of a MF [Madiyevskiy, 1968]. The nonspecific character of the reactions to the MF was noted in studying reactions of the CNS [Kholodov, 1966] and in studying immunological reactions [Vasil'yev, 1968]. Therefore, it is difficult and perhaps even completely impossible to designate the actuating factor by the early reactions of individual organs or systems.

## The Dependence of Magnetobiological Effects on the Characteristics of the Biological Object

In conducting magnetobiological experiments, it was revealed that the effect depends on characteristics of the biological object. Of primary importance is the level of its evolutionary organization. Certain fragmentary reports indicate the possibility of a decrease in magnetic-sensitivity in evolutionary sequence. For example, an unconditioned motor reaction was observed in planarians in a MF [Cherkashin et al., 1965], a conditioned motor reflex /128 to the MF could be developed in fish [Kholodov, 1959; Lissman, 1958], but in birds and mammals a MF of similar intensity could only change the conditioned-reflex reactions developed in response to other stimuli [Kholodov, 1966].

More accurately established was the dependence of magnetic sensitivity on age. The MF had a stronger effect on embryos and the developing organism than on adults [Barnoti, 1960; Aminev, 1966, et al.].

A relation is noted between magnetobiological effects and the seasons. For example, electrical activity in the abdominal nerve chain of the river crayfish, under the influence of a MF of the very same intensity, changed more markedly in autumn and winter than in summer and spring [Luk'yanova, 1966].

Individual differences are revealed in nearly all magnetobiological studies. It was also discovered that a MF, which did not affect labyrinth training processes in fish isolated from the others, began to show its effect in training the same fish in a school. This led to a hypothesis about the "collective reception" of the MF [Aminev, 1966]. This shows that results of studying the /129
sensitivity of individual organs and organisms can only with considerable reservations be transferred to reactions of the entire biosphere.

Finally, the dependence of the MF effect on the initial functional condition must be indicated. Using the same MF, a reaction was not observed in the same object every time [Kholodov, 1966 et al.]. The stability of the reaction (percentage ratio of the number of reactions to the number of influences) could be increased by injecting adrenalin into the blood of a rabbit. A functional load on the spinal cord or kidneys intensified reactions of the corresponding organs to the MF [Rassadin, 1966].

We should note that the threshold effect of the MF is most often detected when the MF intensity is 50 - 100 oersteds. Also used were indices such as oxygen absorption of isolated tissue [Pereira et al., 1967], EEG [Kholodov, 1966] or hematological changes [Dernov et al., 1968]. In these cases, examples of damage are possible, as individual experimental data show that artificial MF, with an intensity close to that of the geomagnetic field (GMF), can have a biological effect.

## The Biological Effect of GMF and Weak Artificial MF /130

In recent years it has been most often assumed [Chizhevskiy, 1963; Presman, 1968 et al.], that the most likely candidate for the role of mediator between solar activity and the biosphere would be GMF fluctuations caused by solar

corpuscles. Many years of observations, conducted in Leningrad [Ryvkin, 1966], Sverdlovsk [Novikova et al., 1968], Irkutsk [Platonova et al., 1968] have shown that an increase of magnetic activity according to the K-index (arbitrary ten-point scale of GMF fluctuations from 0.00004 to 0.005 oersted) is correlated with an increase in the number of cases of various diseases (mostly diseases of the cardiovascular system) and the number of cases of death. These results of heliobiological research indicate the practical necessity of organizing a medical-biological solar service.

It must be mentioned that the GMF varies in intensity not only in time, but also in space. The latter concerns magnetic anomalies and in particular the Kursk magnetic anomaly, where the vertical component of the GMF is 2 - 3 times higher than its level in neighboring regions. Comparing the rate of sickness in the population of the Kursk and Belgorod provinces with corresponding indices in the Perm province and the Primorye Territory, I. V. Dardymov /131
[1966] suggests that the increased amount of hypertension, nephritis, malignant tumors and rheumatism is related to the effect of an increased GMF. The results of this work provoked a great deal of criticism about the method of comparison, but it properly raises the question of the possible effect of GMF anomalies on the biosphere. A comparison of the sick rate of the population of Belgorod province, living under the conditions of the magnetic anomaly, has shown that the number of cases of neuro-psychic and hypertension ailments in the anomalous areas is 160%, and rheumatism of the heart, vascular disorders of the CNS and eczema are 130% in comparison with sick rates in neighboring regions with a normal GMF [Travkin and Kolesnikov, 1969]. The task of future researchers will be to conduct more detailed comparisons of biocenoses of neighboring provinces with a different GMF intensity.

The possibility of an effect of increased GMF on a biological object was shown by M. Ye. Shumakov [1967], who observed an increase in motor activity in caged birds after transporting them from the Kaliningrad province (Rabochiy /132
settlement) to the area of the Kursk magnetic anomaly (Gubkin).

Thus, there are already certain facts which indicate that natural changes in the GMF can affect a biological object.

A great deal of medical data, such as the number of cases of diseases, is often evaluated by subjective indices, depending on the qualification of the researcher, the refinement of diagnostic methods, etc. Therefore, using purely quantitative indices of the functional state of the healthy human organism (number of leucocytes in peripheral blood [Shultz, 1964], sensitivity to various stimuli [Fridman et al., 1967], etc.) gives more detailed and objective information about the relationship between biological processes and fluctuations in GMF intensity. Objectivity increases still more when transferring to experiments on animals. Motor activity in insects [Chernyshov, 1968] and oxygen consumption of molluscs [Barnvell, 1964] closely correlate with GMF fluctuations.

Not considering in detail the more than ancient history of the geomagnetic theory about the orientation of birds, we note that even up to the present day /133 it has a few supporters and a greater number of opponents [Met'yus, 1968].

In this general statement of the ecological importance of the GMF for the biosphere, geomagnetic orientation of birds is too particular a subject. Actually, in recent years the hypothesis about the geomagnetic orientation of animals has been proven in a wide circle of objects.

It has been reported that fish in an unfamiliar reservoir move primarily in the direction of the magnetic meridian, if other stronger orienting stimuli do not act on them [Poddubnyy, 1965]. Many insects prefer to land and rest with the axis of their body in a north-south or west-east direction [G. Bekker, 1966]. Orientation to GMF was observed in worms and molluscs [Braun, 1966], when under laboratory conditions they crawled out of an artificial nest onto a broad platform.

These facts indicate that orientation to the GMF is easier to reveal in many animals than in birds; this phenomenon can be considered as a general biological problem.

Although many questions remain unanswered about the mechanism of orientation in different animals in the GMF, the very existence of such an orientation is receiving wider acceptance. /134

The possibility of the biological effect of a weak GMF is indicated by a great deal of experimental data. Studying changes in the frequency of contractions of an isolated frog heart, A. K. Podshibyakin [1968] noted that the specimens in a state of hypoxia reacted to an increase in the MF intensity of 0.006 Oe. In planarians, it was shown that they change orientation in an artificial MF with an intensity of 0.05 Oe faster than in a MF with an intensity of 4 Oe. [Braun, 1966]. Motor activity in birds increased even in a MF with an intensity of 0.7 Oe [El'darov and Kholodov, 1963].

Therefore, the hypothesis about the effect of GMF fluctuations on biological objects has received direct experimental verification.

However, the problem cannot be considered finally decided. In this material we have already indicated various difficulties which develop in attempting to translate results of experiments to natural conditions of the interacting GMF and biosphere. Now we want to turn our attention to one other factor. Since the action of MF can affect the activity of every system in the organism and any stage of its development, the result of this action can become apparent over a large extent of time and in various forms. Therefore, changes in integral indices of the organism's activity (as an example, disease) can ensue at varying lengths of time after the action occurs. /135

The above reports about the biological effect of various MF can only give information about the initial period in studying the effect of such a penetrating fundamental factor as a MF. Further complex studies will help explain both

details of this mechanism and solve certain purely biological problems, using the MF only as a means of experimentation.

## V. "THE EFFECT OF PERMANENT MAGNETIC FIELDS ON PLANTS"

In this part of the survey, we will consider the effect of a permanent magnetic field on plants and the possible ecological-physiological value of this factor which, evidently, we must consider in planning prolonged medical-biological space experiments. /136

In spite of the fact that the basis for these works was laid down in the Soviet Union by P. V. Savostin as far back as the 1920's, interest in them was not aroused until the end of the 50's when A. V. Krylov and G. A. Tarakanova "discovered" this field of knowledge for plant physiologists. Nevertheless, in a certain sense the works of Savostin can even now be considered as classics in terms of the breadth and depth of the questions they raised; to this day they have no equals in plant magnetobiology. As our purpose does not include a detailed analysis of these works, we will be limited to only the basic factors which arise from them.

Plants are sensitive to the effect of a permanent magnetic field. The magnetic field affects plant growth and its modification (growth movements), gaseous exchange, absorption of minerals, movement of protoplasm in the cell, etc.

The effectiveness of the field depends on its intensity and configuration. However, there is no direct correlation between the field intensity and the character of the response reaction to it. It acts through many channels simultaneously, and therefore the final reaction often does not correspond to the one expected. /137

Besides the factors enumerated above, determined by characteristics of the field, its effectiveness is also determined by the duration and

physiological condition of the plant organism, that is: by the stage of ontogenesis, the daily rhythm of metabolism, general condition, and functional intensity of metabolism.

The informative and energy action of the environment play far from the least significant role here, levelling or, on the contrary, intensifying the effect of the basic factor. In the last analysis, P. V. Savostin comes to the conclusion that the Earth's magnetic field is a necessary factor in the external environment for higher plants, without which their development would, as a result, be disturbed. Therefore, the prolonged existence of plant forms is impossible without a magnetic field.

About 25 years passed before interest was again awakened in the biological effect of the magnetic field on plants. The basis of the new stage of research was laid down by A. V. Krylov and G. A. Tarakanova in the USSR and by Odes in /138
Great Britain [1961], for whom the biological effect of the field was related to magnetotropism. To the first group, this term meant the accelerated germination of seeds, oriented before germination toward the south magnetic pole, in comparison with those oriented toward the north pole, as well as the increased growth of roots and stems of seedlings of the "southern" variety in comparison with the "northern" and the turning of the root system for the latter toward the south (properly tropism). They observed this reaction in both the Earth's magnetic field and in an artificial field, whose intensity reached 400 Oe.

In contrast to A. V. Krylov, to Odes magnetotropism meant the bending of the rootlet of watercress seedling in an inhomogeneous magnetic field with a large gradient toward the lower gradient of the field.

A. V. Krylov himself attached great importance to the discovery of this phenomenon. He thought that explaining the mechanism of magnetotropism shed light on the nature of polarity in plants, on the mechanism of photosynthesis, the growth mechanisms, etc. Not denying the importance of this fact, we /139

nevertheless note, first of all, that no one except the authors of the discovery have successfully observed, in a sufficiently homogeneous field, bending of the root system, growing in a direction from one pole to the other. Secondly, the phenomenon of the unequal germination rate of a seed in turning its embryo toward different magnetic poles was first noted by M. Pum [1957]. However, in view of the poor "conclusiveness" of his tests (they were conducted on only a few plants), the phenomenon was disregarded by biologists. But an extremely curious fact resulted from his tests: in a homogeneous field, germination could be accelerated not only toward the "south", but also toward the "north". Evidently, it is not only a matter of the tests of these authors using different plants (A. V. Krylov as a rule used corn and wheat, Pum — beans), but a different field intensity was also used (Krylov used 0.5 oersted — 400 oersteds, and Pum used 400 oersteds). This is far from being unimportant for the formation of responsive reactions to the longitudinal direction of the field relative to the axis of the root.

At the present time there is an adequate number of facts supporting the /140
tests of A. V. Krylov and G. A. Tarakanova regarding the existence of differences in germination rate and rate of subsequent growth of the root system in various orientations of the seed, relative to the field intensity vector (with or against the lines of force) [Abros'kin, V. V., 1965, Novitskiy, Yu. I., Strekova, V. Yu., Tarakanova, G. A., Prudnikova, V. P., 1965, Chuvayev, P. P., 1965, etc.]. The tests of Pittman [1963-1969], having proven the existence of magnetotropism of the root system in agricultural crops under natural conditions, discovered essentially a third form of magnetotropism — tropism of the roots relative to transverse and longitudinal directions of the lines of force of the Earth's magnetic field. They are not, therefore, a verification of the "polar" tropism of A. V. Krylov. Nevertheless, the possibility cannot be excluded that in the future conditions might be found to reproduce polar tropism which will have to be considered as a real phenomenon. First of all, it must evidently be sought in an inhomogeneous field caused by various configurations of polar terminals symmetrical to one another, i.e., it must be sought first of all as mixed tropism. As the phenomenon of polar tropism is itself ambig- /141
uous, i.e., as mentioned above, it depends on the nature of the plant and

the strength of the magnetic field, growth inversions must be expected when parameters of the field are changed, that is, tropism rotations, as indicated by P. P. Chuvayev [1966] in his time. Of course, the physiological condition of the plant, determined by a number of external and internal factors, will also affect the extent of inversion. Therefore, when maximum yield of vegetative mass is needed from the cultivation of higher plants, the distribution of the root system in space as a factor in the optimum use of minerals in the circulating system of a spacecraft can be determined to a considerable degree by the structure of the local magnetic field, and thus can affect the level of this maximum. However, at the present time we do not have specific recommendations about permissible variations in the level and gradient of the field in comparison with that of the Earth, as the question as a whole is still poorly researched.

Stem tropism. Regarding cases of this phenomenon, we find only a short description with the interpretation of P. P. Chuvayev [1965].

Depending on the location of the plant in relation to cardinal points /142
and its latitude, the angle at which a cereal coleoptile* bends changes relative to the coordinate axes. However, the author of this work considers Coriolis forces responsible for this phenomenon, along with the magnetism of the Earth. As a whole, besides the observations of P. V. Savostin on disturbances of mutation movements of peas in a strong magnetic field, at present no other evidence has yet been obtained on the effect of the magnetic field on tropic movements of stems.

## Growth in a Permanent Magnetic Field

The growth of plants placed wholly in a magnetic field (especially a homogeneous one) has been studied by almost no one. Essentially all the tests studying the growth process are related either to the first stages of seed germination and the growth of seedlings in a magnetic field, or to those cases when only part of the plant is in the field all the time and other parts

*Translator's Note. This is the first leaf in monocotyledon seedlings.

extend beyond its limits. In the latter case, this is, as a rule, the roots and more rarely the tops of the stems. Thus, the factors determining the degree of action in these cases are field intensity, its gradient, and the physiological significance of the organ (subjected to the action) in the life /143
of the plant. At average, low field intensities growth will, evidently, be determined by the field gradient. On the other hand, at low gradients, the field intensity seems to be the factor which determines growth. Let us consider these cases. The effect of a very weak permanent magnetic field on growth was studied by P. P. Chuvayev et al., [1967]. Rye, corn, and bean seeds were germinated in the dark in an ultraweak homogeneous magnetic field, produced by using Helmholtz rings or a special solenoid with a square cross section, for 7 - 10 days. The field inside the rings varied between $5.10^{-4}$ - $10^{-3}$ oersteds; in the solenoid — up to 10 oersteds; and in Permalloy chambers — up to $10^{-4}$ - $10^{-5}$ oersteds. The author succeeded in showing that rye and buckwheat seeds germinate in an ultraweak field and their growth proceeds generally at the same rate as in a magnetic field (up to the seventh day of growth). However, embryonic rootlets are larger along the diameter in this field. As the observations of these same authors on the growth of isolated wheat roots showed, the large diameter of the rootlets in the ultraweak field is caused by a delay in tissue differentiation.

A thicker layer is also preserved in the primary root, whose surface is covered with tumor-like formations.

In regard to lower plants, raising chlorella (Chlorella vulgaris) and /144
euglena (Euglena viridis) under these conditions did not, after five weeks in a Helmholtz ring field, lead to significant differences in the test cultures in comparison with controls in optical microscope observations. Only in Azotobacter chrooccum and yeast (Sacch. cerevisiae) after 3.5 - 4 weeks was a delay in the reproduction rate of cells observed, and an increase in the size of the latter.

These authors also mentioned that in a weak field ($10^{-4}$ oersteds) differences in germination rates disappear in seeds oriented with and against the

magnetic field intensity vector. Of vital importance is the fact that, according to the observations of the authors, placing the germinating seeds in a geomagnetic\field every day for 1.5 - 2 hours restored differences in germination rate.

In the weak homogeneous magnetic field of Helmholtz rings, germination was studied in seeds of "Vyatka" rye, "Golozernyy" oats, "Kuzminskiye" beans and other crops. The effect of two intensities of 10 and 20 oersteds was /145
studied, directed along and against the vector of the Earth's magnetic field. It has been successfully shown [Tarakanova, G. A., Strekova, V. Yu., Prudnikova, V. P., Novitskiy Yu. I., 1965] that in both cases the orientation of seeds with embryos along the intensity vector — more correctly along the horizontal component of this vector — increases the growth rates of the seeds in comparison with other directions of the field. This difference does not on the average exceed 15 - 20%. There is generally the same pattern in the horizontal application of a permanent magnetic field on the horizontal component of the vector of the Earth's field intensity.

In one case of prolonged cultivation of beans in light, in conditions where their root system was continuously in a homogeneous field 40 times greater than that of the Earth (20 oersteds) and the part above the ground extended beyond the limits of this field [G. A. Takakanova, 1968], after 30 days a progressive increase in the length of the root system in comparison with the control was ascertained, despite the fact that, in general, there were indications that the process had an unfavorable course in a magnetic field — blackening and increased dying of the root ends. Nevertheless, it was concluded that on the whole a field that is much stranger than the natural field is an /146
unfavorable factor for growth.

In an inhomogeneous field with an intensity of 60 oersteds (vertical) and 4000 oersteds and 12,000 oersteds (horizontal) — the root system of beans in the field for nearly a week of germination, experienced, in the first case, a stimulating effect toward the pole, and in the other two, an inhibiting effect.

In the latter cases this was primarily expressed in a decrease in the length of the roots and their distortion. The stimulating effect of the field on growth could reach 20%; the inhibiting effect — 25%. In the light, these indices were somewhat higher.

As revealed in cytological studies of areas of the root system exposed to the effect of the magnetic field, underlying the external effect of a changed growth pattern is the action of the field on the process of cell division and expansion in the growth zone. Even in the case of apparent "stimulation" of growth by the magnetic field and in the case of its inhibition, a lag in cell division is observed and, therefore, the apparent growth effect is often determined by the condition and reaction of the expansion zone to the magnetic field. A similar analysis of the growth process at a cytological /147 level in a magnetic field is given in the works of V. Yu. Strekova [1965, 1967, 1968, 1969]. The mechanism of the magnetic field effect on the expansion zone has not been investigated. But the fact that the effect of the field on growth is often at just this point is verified in relation to the great speed of the reaction in relation to the root tip of a 3 - 4 day-old rye seedling placed in a Helmholtz ring in a thermostatically controlled glass chamber when a weak magnetic field of 18 oersteds is activated. A 30-minute exposure in the magnetic field, alternating with intervals of the same length "outside the field", gives a very clear representation of the nature of its action, expressed as definite inhibition ("Vyatka" rye) or acceleration ("Hybrid-2" rye) of root growth, observed in a horizontal microscope. This is compared to intermediate intervals when the direction of the field intensity vector was combined with the intensity vector of the natural magnetic field. Actuating a field of opposite direction does not on the average change the increase for the time of exposure in comparison with the control; it reliably increases the coefficient of increase variableness on the average for shorter intervals in comparison with the control. [Novitskiy, Yu. I., Strekova, V. Yu., Tarakanova, G. A., /148 1966]. The percentage of growth increase in a magnetic field of natural direction fluctuates from 5 to 15. According to the observations of A. V. Nikulin

and F. F. Leis [1967], the reaction to the direction of the field, besides being determined by the parameters of the field, can also be determined by the biosymmetrization of the seed. Thus, seedlings from the left corn grains grow faster on being oriented to the magnetic north, and those from the right — to the magnetic south. The role of dissymmetry in plants, in determining the character of their reaction to the magnetic pole of the Earth, is discussed in detail in the monograph of Yu. G. Sulima [1970], and we shall not dwell on it here. Novitskiy, Yu. I. and Fedorova, O. Ye. [1969] attempted to add the concept of biosymmetry to studying the reaction of seedlings to the magnetic field in the above-mentioned tests with Helmholtz rings. However, under these specific test conditions, the reaction of left, right, and symmetrical seedlings to the magnetic field was the same: growth was inhibited by the field (true, least reliably for right ones, and most reliably, $p < 0.001$, for symmetrical ones) and did not change, on the average, for right and left seeds (and very often for symmetrical seeds as well) when the field was reversed. This does /149 not exclude, of course, the possibility that these differences could be observed at other field intensities.

All this confirms the idea that it is very inaccurate to consider the magnetic field as a weak stimulus. Sharing the opinion of Yu. A. Kholodov, we can qualify it rather as an "odd" stimulus of a natural order in a range close to the range of intensities of the Earth's magnetic field, and of an unnatural order in all other ranges. In this connection, one cannot help but mention that a number of Russian works [Krylov, A. V., 1961, Larin, 1963, Novitskiy, Yu. I., 1967, 1969], as well as the works of Pittman [1962-1969] verify the idea that the Earth's magnetic field is a natural factor in the distribution of the root system in the soil. Evidence of the controlling influence of this factor is presented by tests with an artificial field causing a change in the direction of intensified seed germination, when their original position is preserved in relation to solar and magnetic coordinates of the Earth's pole [Novitskiy, Yu. I., Strekova, V. Yu., Tarakanova, G. A., Prudnikova, V. P., 1966]. It is also indicated by corresponding studies of the orientation /150 of root systems under the natural conditions of the anomalous field of the

Kursk magnetic anomaly, where the characteristic primary distribution of root furrows in two main directions N-S and E-W in sugar beets is shifted after a change in magnetic declination. We realize that it is theoretically improper to reduce the entire orientation of the root system in the soil of many plants to tropic deflection under the influence of the Earth's magnetic field. We also realize that the internal nature and physiological nature of this phenomenon remain completely unknown. We are also convinced that the other forms of tropisms (thermo-, hydro-, photo- and sali-tropism) have their share in this distribution. Here, as in all physiological processes and effects, Blekman's principle of limiting factors plays an important role.

Returning now to the effect of a magnetic field on plants at cellular, ultracellular, and subcellular levels, we must emphasize that, first of all, damage to the cell division cycle is one of the most severe results of the field. According to V. Yu. Strekova, the prophase of the cell is the most probable link in the cell cycle where the action of field forces is manifested. /151
She feels that the magnetic field by itself, that is to say, independently, can cause damage such as bridges, fragments, microcardia, change in the RNA content of the cell, etc. (in literal agreement with the data obtained earlier by M. R. Chelestre, to be sure, on other objects and with other magnetic field intensities, 1957). A number of other authors: A. A. Pozolotin and associates [1965, 1966, 1968, 1969, 1970], studying the effect of a magnetic field of various intensities against a different radiation background, suggest that the field itself cannot cause these disturbances, but can only contribute to those which are produced by radiation effects or other causes, i.e., in other words, it causes disturbances, depending on the level of the radiation. This vital moment concerning the mechanism of a permanent magnetic field cannot be circumvented in the discussion, as the position generally accepted in other areas of magnetobiology is that the effect of the magnetic field decreases the radiation syndrome and reduces sensitivity to the radiation, while /152
radiation increases sensitivity to the magnetic field.

However, in the tests of P. A. Pozolitin and his associates, short exposures of test objects to a magnetic field (1 - 5 min) are utilized, and

exposure to radiation primarily precedes magnetic treatment. The test subject was swollen seeds in the sprouting period. The most important conclusion which results from these tests is that, depending on the radiation dosage, the field can either stimulate or depress growth in the post-radiation period, change the course of mitosis, etc. The authors believe that the permanent field itself, independent of its intensity, although it has a biological effect, does not interfere with the course of mitosis, and does not cause chromosome aberrations, although it is able to increase mitotic activity in the meristem of peas at the beginning of the first mitosis after the action. The permanent magnetic field proper can be an active modifier of radiation injury. The same field by itself (8.3 kilo oersteds) does not affect the mitotic activity in the root meristem of irradiated and nonirradiated pine seeds. The essential feature of the tests enumerated above, as already emphasized above in contrast to the tests of V. Yu. Strekova and her coauthors and the tests of M. R. Chelestre, is the relative brief exposure in the magnetic field, measured in /153 minutes and hours, whereas in the tests of V. Yu. Strekova it was close to several days.

Thus, the ambiguity of reactions to an applied magnetic field depends both on the parameters of that field and on the parameters of the preceding exposure.

To date it has also been shown quite clearly that the individual nature of the reaction is also determined by physiological-genetic characteristics of the plant. V. G. Shakhvazov and his coauthors (1965) feel that the heterosis forms of hybrids are, as a rule, less sensitive to the influence of the field. This point of view agrees with that stated earlier by P. V. Savostin [1930] to the effect that purely linear varieties are usually more susceptible to the action of the field in comparison with nonlinear ones. As follows from the works of A. I. Mochalkin, Rik and Batygin [1962] — in which the reaction of germinating rye, wheat and barley seeds to different lengths of time spent in a field of several intensities was studied — the growth rates

of the seedlings after magnetic treatment in each group of plants are changed very individually, in more than one way, thereby verifying its dependence /154 along with other factors on the genetic nature of the tested material.

So long as the growth process is based on the material and energy resources of the cell, we feel it is necessary to discuss the question of the effect of a magnetic field on cellular energy exchange in plants. As the magnetic flux density within the magnetic field intensity range (with which biology deals) is relatively small, and the magnetic permeability of biological objects and their individual parts also does not greatly differ from that of the environment, it is difficult to expect the field to have a direct energy effect on the majority of processes occurring in the cell.

However, because the energy processes of a living object represent an interconnected chain of exo- and endothermic reactions, disturbances in the course of one or several of them, which are magnetically vulnerable, entail a change in the energy balance of the organism — in the majority of cases, for the worse. This occurs because the magnetic field is not a strong, decisive factor, and the equilibrium of a living system seems to us to be a transient /155 equilibrium. The magnetic field, to a certain degree, stabilizes the movement of charged structures, which are properly ion fluxes in the cell, native protein micelles, and membranes.

Thus, the paradox is that, on the one hand, the magnetic field should in certain cases help to maintain the nativeness of a living structure, especially under conditions of decreased exchange in the organism. On the other hand, it should limit the intensity of exchange in the actively growing organism, as its stabilizing effect is vectoral in nature, i.e., compulsory. From this it must be expected that the magnetic field will have a disproportionate effect on exchange, even in its action (externally expressed by stimulation) on individual aspects. Because of this, this action is temporary.

The study of the energy state of plants in a magnetic field has been dealt with eseentially only in the works of G. A. Tarakanova and her coauthors, carried out exclusively during the last ten years.

The author conducted her research on a crop of beans of the "Kuzminskiye" variety, grown in the dark on river sand or agar-agar. The seedlings were /156
4 - 7 days old. The field in which the seeds were germinated was an inhomogeneous one on the order of 60 oersteds; 4.5 and 12 kilo oersteds. As indices of certain aspects of the energy state of the plants in the field, the author chose the degree of conjugation of respiration and phosphorylation processes. It is generally accepted that a change in the conjugation of these processes toward an increase indicates a simultaneous increase in the effectiveness of respiration, and a decrease of conjugation — weakening of effectiveness. The ratio P/O is the index of this conjunction. In preliminary research, she showed that germination in a magnetic field leads as a rule to a decrease in the object's oxygen consumption, depending on its biological category, and in a homogeneous and in an inhomogeneous field of varying intensities from 10 oersteds to 12 kilo oersteds. In strong fields, there is an aftereffect, expressed as an increase in oxygen consumption after the object is removed from the field. In general, the discharge of carbon dioxide is also decreased proportionally, so that the respiratory coefficient, as a whole, does not change. The study of energy ratios against this background, which characterizes the state of respiratory gas exchange, indicated the following. The immediate /157
result of the field on individual roots of bean seedlings was either to stimulate oxygen consumption in the presence of optimum concentrations of dinitrophenol (in the case of a field on the order of 60 oersteds), i.e., increasing conjugation, or to decrease oxygen consumption (in fields of 4.5 and 12 kilo oersteds), i.e., disturbing oxidation and phosphorylation. It can be assumed that, to a certain degree, the immediate result will give us an idea of the course of the processes directly in the field itself, whereas a far-removed result indicates the recovery forces of the organism aimed at eliminating the developing imbalance in exchange. In the same way as Zhitaru observed in an

electromagnetic pulsed field, the effect of a weak field has practically no aftereffect, whereas the effect of a strong field is characterized by the development of a reverse process in the aftereffect process (in this case — increased conjugation), gradually returning to normal. This also means that, in the case of a longer stay in a magnetic field of great intensity, the compensatory mechanisms of the cell can hardly restore the original situation in the energy exchange mechanism. As a result, either a partial loss of cellular viability can appear or death. In this sense, studying the character of /158
the aftereffect of the field indicates the reanimation capacity of the organ in response to the influence of the field and the degree of damage produced.

Since energy in living cells, apart from ATP and ADP, is accumulated in the form of compounds which contain thiol groups through the formation of macro-ergic thio| ether|bonds, G. A. Tarakanova and coauthors [1969] considered the question of the possible effect of a permanent magnetic field on a change in the content of thiol groups. It was successfully shown that in those cases when the field has no effect on growth (swelling rye seeds in a field of 20 oersteds), the content of SH-groups also does not change in comparison with the control. At the same time, in a field of 4 kilo oersteds which has a pronounced suppressing effect on the growth of bean roots, a significant reliable reduction in the content of SH-groups is observed. Thus, it becomes clear that the field does not act directly on the thioether groups, but through the growth process. Still another series of works, dealing with the energy state of plants in a magnetic field, concerns the interconnection between the action of fields of various intensity and spontaneous chemiluminescence of /159
the roots of bean seedlings raised in this field. Authors [Ya. G. Doskach, Yu. V. Strekova, G. A. Tarakanova, B. N. Tarusov, etc.] have succeeded in showing that the level of spontaneous chemiluminescence "is correlated" with the intensity of the growth process in a magnetic field: if growth is suppressed in the field, then the level of chemiluminescence also drops; if growth is stimulated, then this level increases. From the data obtained, they conclude that the field has a direct effect on the intensity of ultraweak luminescence;

for many reasons we feel this is extremely questionable. Firstly, the mechanism of this action in fields of such relatively low intensities is completely unknown. Secondly, a similar interrelation between growth and the level of ultraweak luminescence is also observed in any other reactions. Finally, thirdly, a change in the character of the effect of a field with the very same intensity on growth, depending on a number of attendant factors, causes a corresponding change in the level of spontaneous ultraweak luminescence [Travkin, M. P., Doskoch, V. G., Novitskiy, Yu. I., etc., 1970]. Therefore, the study of spontaneous chemiluminescence, as an indication of the stability level in the course of oxidizing processes in the cell, has some value for /160
the general characteristics of cell energy, but is only indirectly connected with the mechanism of the field action.

Above we have been discussing the energy of dark seedlings in a magnetic field. However, of no less interest are questions of light energetics and photosynthesis. There are comparatively few works in this field, and they have been conducted primarily on two-week old wheat seedlings raised outside a field. I. A. Tarchevskiy and A. I. Zabotina and their coworkers, in a number of works using a permanent magnetic field of 8 - 10 thousand kilo oersteds, succeeded in showing that photosynthesis decreases 20% in a magnetic field after many hours of exposure. This decrease is accompanied by damage to the photosynthetic phosphorylation and a ratio change in the distribution of tracers in carbohydrates and amino acids. This change is reliable, but nonspecific, which is characteristic of many extreme-acting factors and consists of a decrease in tracers activated in free sugars and an increase in $C^{14}$ activated in free amino acids. As A. I. Zabotin considers, the acceptor of the /161
magnetic field in the cell seems to be the macromolecules of cytoplasm, whose fine structure is possibly deformed under the influence of the magnetic field.

It is possible to sum up what is known today on the action of a permanent magnetic field on plants as follows:

1. As a rule, the effect in time of a magnetic field on germinating seeds and seedlings was examined.

2. In the majority of cases, the plants were not entirely in the field, but only a part of them, primarily the root system.

3. Both high and low intensity fields were effective.

The high intensity fields (over 1000 oersteds) as a rule inhibit root growth; low fields (10, 20, 60 oersteds) stimulate it. Both depression and stimulation of growth is accompanied by disturbances to mitotic activity in root cells. Evidently the expansion zone does not play a decisive role in determining the final reaction.

4. The gradient of the field and its direction determine the distribution of the root system in space and, therefore, can affect the mineral supply of the plants.

5. High intensity fields affect photosynthesis, reducing its intensity and directional changes toward the formation of their basic products. /162

6. The gaseous and energy regime of the vegetable cell is changed: oxygen consumption is reduced, the conjunction of oxidation and phosphorylation processes is changed.

7. Placing plants in an ultraweak field ($10^{-3}$ - $10^{-4}$ oersteds) leads to a gradual deformation of the plant, which is restored by placing the plants briefly in a normal field.

8. In the majority of cases, the effect of an increased or ultraweak field is reversed when the plants are returned to normal conditions after the object has spent not more than a week in the altered field.

Evidently, 10 - 15 changes in field intensity in both directions are permissible. However, a final decision on this question needs special experimentation.

9. At the present time, it is impossible to construct a good basic representation of the mechanism of the field action, or of the seriousness of aftereffects of this effect on the genetic plane, in view of the lack of special and reliable experimental proofs.

Concluding this section of the chapter about plants with such vague conclusions, we feel it is our duty to note that it would be incorrect to imagine that the magnetic field only has an effect on objects with a rather high level of metabolism. Thus, for example, dry barley, wheat, etc. seeds, kept in a magnetic field of 450 oersteds, experience an aftereffect in the form of a change in structure and an increase in yield. There are optimum and maximum lengths of time spent in the field, which affect the further development of the plants in different ways. For barley, for example, two days in this field have a positive effect in the form of a small reliable increase in the yield, but one or three days depresses it [Novitskiy, Yu. I., Strekova, V. Yu., Tarakanova, G. A., Prudnikova, V. P., 1965]. According to the data of M. A. Khvedelidze and his associates [1968], wheat of the Ubkho-II variety is even more sensitive to a magnetic field. /163

It was also shown that the field is an active protective factor against the effect of high temperature on the seeds [Novitskiy, 1965, 1968] if they are located along the lines of force of a horizontal magnetic field. This is far from exhausting the range of aftereffects of a plant placed in a permanent field, which must be considered in organizing prolonged space experiments. /164

## Brief Conclusion

We have considered the effect of electromagnetic waves of various ranges on animals and man, low-frequency electric and magnetic fields on the same

objects, a constant electric field on animals and man, as well as a constant magnetic field on plants, animals and man. Not included were problems of the influence of electric fields on plants and micro-organisms, as well as magnetic fields on micro-organisms and electromagnetic fields on plants and micro-organisms. This is not because there is not corresponding information, but because this information is too little and contradictory and does not contain those quantitative criteria for comparison used by the authors in writing the sections in this chapter. The study of the effect of an electric field, /165
especially a high-intensity field, also involves, as a rule, including in the sphere of action still another actuating factor — air ions, which for completely obvious reasons cannot be seriously considered here. For plants, except water plants, this question is in turn connected with the question of reaction to stimulation caused by electric currents, since under normal conditions their stem (the stalk) is a conductor, connecting the atmosphere with the surface of a zero potential (the ground). In general, the distinctive feature of the action of electric fields in particular, and electromagnetic waves to a lesser degree, is the dependence of the field effectiveness on the geometry of the object being affected. This is scarcely considered in biological studies, and neither is the degree of its grounding, which was just mentioned. Attention is concentrated, as a rule, on parameters of the field and the physiological state of the object. It is undoubtedly necessary to know the physical properties of the object of study. But at this point, our knowledge is close to zero. Therefore, questions on the primary action of any electromagnetic factors are, to a considerable degree, hypothetical rather than demonstrated. We are referring to the primary mechanisms of the action, because the general /166
character of disturbances is basically the same for the action of extreme factors of an electromagnetic nature.

What are the common shortcomings in the biological action of these factors?

First of all, there is frequently a lack of accurate descriptions of parameters of the effective factor and those accompanying it.

Secondly, there is a lack, no less frequent, of detailed characteristics about the object of study, physiological, morphological, etc.

Thirdly, there is an almost complete lack of genetic research in this field.

Fourthly, there is the relative short duration of the experiments.

Nevertheless, the accumulated facts are so important that they must be considered in organizing prolonged space experiments with living objects. If it would be necessary to arrange electromagnetic factors according to the degree of their effect with equal power, and depending on the time of the effect, then they would be arranged in the following sequence: superhigh frequency, ultrahigh frequency, radio-frequencies, variable and constant electric /167
fields, variable magnetic fields, constant magnetic fields with a large gradient, constant homogeneous magnetic fields, and absence of the latter. The last point does not meet the requisite conditions, but illustrates the necessity of some kind of average background against which the vital activity of the organism should proceed, and is evidently related not only to magnetic fields, but also to other factors. On the other hand, if it is necessary to characterize organisms by the degree of their resistance to electromagnetic action, we should note, primarily, that functional load, functional instability, physiological activity, youth, pure strain — are the aspects which make them more sensitive to this action.

The last factor (pure strain) is extremely debatable; all the others connected with the intensity of metabolism are not subject to doubt. From this it would seem but a direct step to acknowledging that damage to the functioning of the cell's membrane apparatus is the primary mechanism of action in all cases of electromagnetic influence. This is because, in the last analysis, /168
this is the connecting link for all the factors which determine the intensity of exchange, other conditions being equal. However, this usually correct

assumption proves to be, on close examination, quite general, for with differing penetrability of these factors into the cell (compare electric and magnetic fields) the extent of their action does not depend on the degree of their penetration. Secondly, in spite of the varying nature of the action (orienting in a magnetic field and disorienting under the thermal action of SHF) their character can be the same. Probably the nonspecific character of many response reactions to electromagnetic action is due to the integrating ability of the organism resulting from the interconnection and interconditionality of the reactions in it. This is sufficient for a simple explanation, but completely inadequate for understanding the essence of the phenomena, and for taking protective or prophylactic measures. Consequently, the latter until now have been achieved on the basis of experiments, i.e., to some degree empirically, which is indicated by the material in this chapter. These experiments are completely inadequate.

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extra-cardial nervous system by increasing the excitability of vagus nerve centers. This conclusion is verified by the fact that a chronotropic effect, caused by the action of the UHF field on the region of the heart or the head, was also observed when vagus nerves in the frog were severed at the point where they leave the brain and when vagosympathetic systems were severed. /178

Balutina, A. P. and T. L. Korobkova. Pathological Changes in the Eyes of Rabbits, Irradiated by a SHF Field. Gigiyena Truda, 4, 1969, pp. 57-58.

Clinical histological changes were observed in the crystalline lens in radiation by SHF microwaves even at such intensities as 5 $mW/cm^2$.

Balutina, A. P. The Effect of a SHF-field on the Human Organ of Sight. Boyenno-meditsinskiy zhurnal (Voenno-med. zhurn.), No. 6, 1969, pp. 42-43:

1. Working with UHF, HF, and SHF equipment — health clinical characteristics.

2. Crystalline lens — the effect of physical and physiotherapeutic factors.

Observing the dynamics of changes in the crystalline lens of people working in industries with SHF field sources, the author notes no clinically perceptible increase in dimness of the congenital type after 3 years of observations.

Baronenko, V. A. and K. F. Timofeyeva. Deystviye elektromagnitnovo polya vysokoy i ul'travysokoy chastoty na organism zhivotnovo i cheloveka. (The Effect of a High and Ultrahigh Frequency Electromagnetic Field on the Animal and Human Organism). Trudy laboratorii elektrobezopasnosti LIOT (Transactions of the Laboratory of Electrosafety, All-Union Scientific Research Institute of Work Safety of the All-Union Central Trade-Union Council [LIOT]), Leningrad, 1958, pp. 48-59. /179

The authors discovered that changes occur primarily in the central nervous system under the influence of UHF.

Baronenko, V. A. and K. F. Timofeyeva. The Effect of HF and UHF Electric Fields on Conditioned-reflex Activity and Certain Unconditioned Functions of Animals and Man. Fiziologicheskiy zhurnal SSSR imeni I. M. Sechenova, X, No. 2, 1959, pp. 203-207.

The authors found that HF and UHF fields (wavelength of 15.6 meters) cause (in people and animals) changes in the indices of conditioned-reflex activity, blood pressure, and pulse and respiration. The authors established a quantitative and qualitative dependence of the field effect on intensity, frequency, and length of time the object spent in the field.

Belitskiy, B. M. and K. G. Knorre. Radiation Protection in Working with SHF Generators. Collection: O biologicheskom vozdeystvii sverkhvysokikh chastot (On the Biological Effect of Superhigh Frequencies). Trudy Instituta gigiyeny truda i professional'nykh zabolevaniy AMN SSSR (Transactions of the Institute of Work Hygiene and Occupational Diseases of the USSR Academy of Medical Sciences), edited by Professor A. A. Letavet, Member of the AMN SSSR, and Assistant Professor Z. V. Gordon, Candidate of Medical Sciences. Moscow. Vol. 1, 1960, pp. 107-118. /180

The basis of any protective device against SHF energy is the use of solid and wire metal screens, as well as screens made of absorbant materials. Their construction depends on the character of the technological process.

Belova, S. F. Changes in the Elasto-tonometric Curve in Rabbits Under the Effect of SHF. Collection: O biologicheskom vozdeystvii sverkhvysokikh chastot (On the Biological Effect of Superhigh Frequencies). Trudy Instituta gigiyeny truda i professional'nykh zabolevaniy AMN SSSR (Works of the Institute of Work Hygiene and Occupational Diseases of the USSR Academy of Medical Sciences), edited by A. A. Letavet, Member of the AMN SSSR, and Z. V. Gordon, Candidate of Medical Sciences. Vol. 1. Moscow 1960, 86-90.

General radiation of animals at SHF with an intensity of 1 $mW/cm^2$ for 3.5 months causes a regular change in the elasto-tonometric curve, expressed in a reduction of apthalmic tone. These changes are a result of disturbed regulation of intraocular pressure and are temporary.

Belova, S. F. On the Effect of Centimeter Waves on the Eyes of Animals. Collection: Gigiyena truda i biologicheskoye deystviye elektromagnitnykh voln radiochastot. (Work Hygiene and the Biological Effect of Radio-Frequency Electromagnetic Waves). Collection of Material of the Third All-union Symposium 24-28 June, 1968. Moscow, 1968, 7-9. /181

Intermittent radiation of animals with 10 cm waves with a power current density (PPM) of 40 $mW/cm^2$ for 9 months causes a varying degree of change in all eye tissues. Similar changes were noted in continuous radiation; however, they developed later and damage to the eyes was less pronounced. The author concludes that intermittent radiation is more dangerous for the eyes than constant radiation.

Belova, S. F. and Z. V. Gordon. The Effect of Centimeter Waves on the Eyes. Byulleten' eksperimental'noy biologii i meditsini (Byull. eksper. biol. i med.), 1956, 41, 4, 43-46.

Tests were made on 25 rabbits. All the animals were subjected to a preliminary ophthalmoscope examination, and some to an examination with a slotted lamp. The eyes of the rabbits were irradiated with waves 10 cm in length at power current density of 110 $mV/cm^2$. Two series of tests were conducted: I — acute and II — chronic.

I. The rabbits were irradiated 1-7 times. Each radiation lasted 1 hour. Immediately after irradiation, redening of the mucous membrane of the eyelid and eyeball was noted. The mucous membrane was somewhat edematous. The cornea was lusterless and edematus. In individual animals infiltration of the cornea was observed with its deeper layer preserved. Pericorneal injection was expressed to various degrees. The pupil was markedly narrowed after irradiation. The iris was hyperemic. Examination with a slotted lamp revealed cloudiness of the crystalline lens in some animals. /182

II. Daily radiation for 1 1/2 months, each radiation lasting 10 min. Immediately after irradiation there was slight irritation of the front part of the eye. After the 3rd radiation, irritations increased. Changes with respect to the crystalline lens developed significantly later in these animals than in the rabbits in the 1st series, and were similar to those observed in acute tests. The bottom of the eye of the rabbits remained normal. Morphological studies of the eyes of the animals verified the observations.

Belokranitskiy, B. M. Changes in the Tigroid Masses* of Neurons Under the Influence of Radiowaves. Fiziologicheskiy zhurnal, Kiev, 12, I, 1966, pp. 70-78.

The most pronounced changes are observed in the vascular system and vegetative centers of the brain under the effect of USW. According to the author, changes are related to degenerative-necrotic processes, primarily of parenchymatous cells in organs rich in reticulo-endothelial elements and endocrine glands, especially the adrenals and sex glands.

Bereznitskaya, A. N. The Effect of 10-centimeter and Ultrashort Waves on the Reproductive Function of Female Mice. Collection: Gigiyna truda i biologicheskoye deystviye elektromagnitnykh voln radiochastot. (Work Hygiene and the Biological Action of Radio-frequency Electromagnetic Waves). Moscow, 1968, pp. 11-13.

Animals irradiated for 5 months with a non-thermogenic intensity developed a disturbed estrous cycle. A lower percentage of interbreeding, inferior offspring (still-births, retarded development, higher post-natal mortality rate). Especially sensitive to radiation were the mice which were at the pubescent stage at the beginning of the effect. The USW range was more active. It is recommended that the data obtained be used to restrict adolescents and pregnant women from working with sources of radiation waves and USW. /183

Bereznitskaya, A. N. Studies of the Gonadotropic Activity of the Pituitary Gland of Female Mice Irradiated with 10-centimeter and Ultrashort Waves. Collection: Gigiyena truda i biologicheskoye deystviye elektromagnitnykh

*Translator's Note: This pertains to Nissl masses of deeply staining substance in the protoplasm of neurons.

voln radiochastot (Work Hygiene and the Giological Effect of Radio-frequency Electromagnetic Waves). (Collection of Material of the Third All-union Symposium) 24-28 June, 1968, Moscow, 1968, pp. 13-15.

Data obtained indicated that the pituitary gland of irradiated females preserves its gonadotropic function; however, its activity is reduced in comparison with the activity of non-irradiated animals. The USW range has a more pronounced effect on the gonadotropic function of the pituitary gland than 10-centimeter waves.

Bychkov, M. S. On the Effect of a Superhigh Frequency Electromagnetic Field on Strychnine poisoning in White Mice. Collection: Trudy Leningradskovo obshchestva yestestviospytateley (Works of the Leningrad Society of Naturalists). Leningrad University Press, Vol. 72, Issue 1, 1961, p. 110.

The effect of microwaves on strychnine tetany (electromyography) was studied and the lifespan of white mice under the effect of thermogenic intensities (PPM from 60 to 125 $mW/cm^2$, radiation lasting from 1 to 3 minutes). A decrease in the resistance of white mice to strychnine poisoning was established under the effect of a SHF field. /184

Bychkov, M. S. and Z. Ye. Moreva. On the Effect of Superhigh Frequency Radio Waves on a Neuro-muscular Specimen of a Frog. Collection: Trudy Leningradskovo obshchestva yestestvoispytateley. (Works of the Leningrad Society of Naturalists). Leningrad University Press, Vol. 71, Issue 1, 1960, p. 78.

In the neuro-muscular specimen of a frog, changes were studied in the excitability of the sciatic nerve (according to the clinical method of N. Ye. Vvedenskiy), and in the chronaxy of the sciatic nerve, alteration currents in muscles, and changes in threshold curves characterizing the excitability of muscles to sinusoidal currents of various frequency under the influences of a SHF field with a PPM from 10 to 200 $mW/cm^2$ and a duration from 1 to 9 minutes. The parabiotic character of functional shifts with a two-phase pattern of changes was established, which corresponds to the thermal narcosis described by N. Ye. Vvedenskiy. Under certain conditions of action on the preliminarily altered nerve, the normalizing, deparabiotic effect of microwaves was observed (for example, removing the equalizing stage of parabiosis).

Bychkov, M. S. On the Neurophysiological Characteristics of the Specific Effect of Superhigh Frequency Radio Waves. Collection: Problemy neurokibernetiki (Problems of Neurocybernetics). Rostov University Press, 1967, p. 17. /185

An increase was established in the membrane potential of muscle fiber in the frog, an increase in the threshold of excitability, a lengthening of the latent and refractory period, a decrease in the conduction rate in the nerve fiber, and an increase in synaptic delay in the myoneural

synapse under the influence of microwaves with an intensity of 5 $\mu W/cm^2$. In the CNS of a narcotized muscle, with PPM intensity of 20 $\mu W/cm^2$ a depression in the commisural activity or cortical neurons and induced potentials in the specific system of the brain was established as well as a blocking of corticofugae connection from the projection cortex to the reticular nucleus of the thalamus.

Varin, I. Ye. On the Question of the Occupational Hazards of Working with Medical UHF Generators. Gigiyena i sanitariya, 1964, No. 1, p. 28-34.

The author studied the health of personnel operating medical UHF generators (wavelength 7.7 m), subjected to the effect of electromagnetic fields with an intensity from 32 to 450 V/m. In the examinees, the author found functional disturbances of the nervous system associated with symptoms of hypotension and bradycardia.

Vladimirova, N. A. The Effect of a UHF Electromagnetic Field on Experimental Radiation Sickness in Animals. Meditsinskaya radiologiya, 4, No. 7, 1959, pp. 14-20.

As a result of repeated 10-minute effects (lasting 15 days) of a UHF field in oligothermal dosage, stimulation of leuco-, erythro- and thrombocytopoiesis was noted with the absence of an expressed effect on the clinical course of radiation sickness. The radiation dosage was 650 R. /186

The author suggests that the effect is connected with the action of the UHF field on the blood-forming organs and on the end fibers of the sympathetic and parasympathetic nervous system, and through them on a number of organs and systems.

Vol'fovskaya, R. N., Yu. A. Osipov, T. V. Kalyada, et al. On the Question of the Combined Effect of a High-frequency Field and X-ray Radiation. Zhurnal Gigiyena i sanitariya, 1961, No. 5, p. 18-23.

On the basis of intensitifed clinical research and dynamic observation data combined with other indicated groups, the authors think it possible to consider the complex of pathological changes which are characteristic of high-frequency currents and Ro". The basic components of this complex are complaints of weakness, headache, drowsiness, pains around the heart, irritability, pains in the extremities, functional disturbances of the central nervous system, changes in the blood — thrombopenia, leukopenia and tendencies toward it, ovary dysfunction. The established symptoms were caused by the combination of the chronic effect of both factors — the high-frequency field and X-ray radiation. The latter as a stronger biological factor leaves its mark on the whole clinical pattern. /187 Persons working in these conditions are required to have preliminary and periodic medical examination. Protection from X-ray radiation requires complete screening of the ionotropic rectifier circuit and the removal of any leaking in the connection between the viewing windows and the walls of

the protective chambers. The HF field might be decreased by changing the design of the worker's station and the HF energy feed into the conductor.

Gvozdikova, A. M., V. S. Anan'yev, I. N. Zenina, and V. I. Zak. The Effect of Constant SHF Electromagnetic Fields on the Central Nervous System. Collection: O biologicheskom deystvii elektromagnitnykh poley radiochastot (On the Biological Effect of Radio-Frequency Electromagnetic Fields). Works of the Laboratory of Radio-Frequency Electromagnetic Fields, Institute of Work Hygiene and Occupational Diseases, AMN USSR, Issue 2, Moscow, 1964, p. 20.

The polymorphic character of EEG changes are described which occur under the influence of constant SHF fields (in 53% of cases — deactivation; in 37% — activation). The greatest sensitivity was to the meter range, less to the decimeter, and the least to centimeter waves.

Gel'fon, I. A., and M. N. Sadchikova. Protein Fractions and Histamine in the Blood under the Effect of Radiowaves of Various Ranges. Collection: O biologicheskom deystvii elektromagnitnykh poley radiochastot (On the Biological Effect of Radio-frequency Electromagnetic Fields). Works of the Laboratory of Radio-frequency Electromagnetic Fields, Institute of Work Hygiene and Occupational Diseases, AMN, SSSR, Issue 2, Moscow, 1964, 133-137.

It was shown that changes in protein content and histamine in human blood /188
depend on the wave range. Shifts are most often observed under the influence of centimeter waves, less often under the effect of short waves, and even in individual persons under the influence of ultrashort and medium waves. Changes were expressed in people as an increase of histamine, total protein and globulins, with pronounced symptoms in apparently healthy individuals.

Gembitskiy, Ye. V., F. A. Kolesnik, and V. M. Malyshev. Changes in the Blood System under the Chronic Effect of a SHF Field. Voyennomeditsinskiy zhurnal. 5, 1969, 21-23.

The authors present the development of changes in the blood system under the chronic effect of a SHF field in the following form: in the early stages — pronounced instability in the number of leukocytes (most often leukocytosis), relative lymphocytosis, monocytosis. Then the reduction in the number of leukocytes is evidently due to the regulatory function of the nervous and endocrine system (and not to changes in marrow).

Ginzburg, D. A., and M. N. Sadchikova. Changes in the Electroencephalogram under the Chronic Effect of Radiowaves. Collection: O biologicheskom deystvii sverkhvysokikh chastot. (On the Biological Effect of Superhigh Frequencies). Works of the Institute of Work Hygiene and Occupational Diseases, AMN SSSR, Issue 2, Moscow, 1964, p. 126.

The results of EEG examination of persons irradiated in industry are given (SHF, UHF, HF). The most pronounced changes were observed in persons with severe symptoms from the action of centimeter waves. The character of the changes (generalized syndrome paroxysmal activity), according to the authors, indicates functional damage at the mesodiencephalic level. /189

Goncharova, N. N. Materialy k gigiyenicheskoy otsenke usloviy truda, rabotayushchikh s istochnikami elektromagnitnykh poley radiochastot (Data on the Hygienic Evaluation of Working Conditions in Operating Radio-frequency Electromagnetic Field Sources). Materialy Ukrainskovo respublicheskovo soveshchanii promyshlennykh i sanitarnykh vrachei i nauchn (Data of the Ukrainian Republic Conference of Industrial and Health Inspectors and Scientists). Session of the Kharkov NII (Scientific Research Institute) of Work Hygiene and Occupational Diseases, Kiev, 1968, 122-124.

The high sensitivity of the nervous system and especially the diencephalic region to the effect of radio-frequency EMF is indicated by the change in the bioelectric activity of the retina (increased amplitude of constant corneo-retinal potential and electroetinogram); weakened excitability of the CNS and intensification of the inhibitory process (lengthening of the response reaction to the sum of threshold stimulations). Shifts are noted in exchange processes. Vascular reaction has a tendency toward vagotonic shifts.

Goncharova, N. N., V. B. Karamyshev, and N. V. Maksimenko. Questions of Work Hygiene in Working with USW Transmitters, used in Television and Broadcasting. Gigiyena truda i profzabolevaniya, 7, 1966, pp. 10-13.

After examination of working conditions in television stations, field intensities were revealed which several times exceed the maximum permissible level (MPL) (5 V/m). Workers operating the USW apparatus displayed shifts in the functional condition of the nervous and cardio-vascular system. With increased work experience, the number of persons with deviations from the normal also increased. /190

Goncharova, N. N., V. V. Karamyshev, N. V. Maksimenko, I. S. Ostrovskaya, and L. I. Yashina. Results of a Comprehensive Study of Meter Range Electromagnetic Fields. Collection: Gigiyena truda i biologicheskoye deystviye elektromagnitnykh voln radiochastot (Work Hygiene and the Biological Effect of Radio-frequency Electromagnetic Waves). Collection of Data from the 3rd All-union Symposium, 24-28 June, 1968, Moscow, 1968, p. 19-31.

A comprehensive clinical-physiological examination revealed a change in the state of their health, exhibited as functional changes in the nervous and cardio-vascular systems. Experimental studies on animals showed a change in indices of the nervous and cardio-vascular system, a reduction

in glycogen reserves and an increase in the level of lactic and pyruvic acids, a change in the spectrum of protein fractions, etc. At the same time, compensatory adaptive reactions were noted in the form of proliferation of cells in connective tissue.

The research revealed the dependence of the functional state of the organism under the effect of USW on the character of the field components, the duration and intensity of radiation. The damage observed indicates shifts in the functional state of the diencephalic region, disturbances in biochemical processes (indices of nitrogen and carbohydrate exchanges in brain tissues), inhibition of reflex activity of the CNS in animals, a change in blood pressure level, hemodynamic damage and morphological shifts. /191

Goncharova, N. N., V. G. Piskunova, V. B. Karamyshev, N. V. Maksimenko, V. S. Anatovskaya, and L. I. Mishchenko. The Clinical-hygienic Characteristics of Working Conditions of Persons Operating High-frequency Equipment. Collection: Voprosy gigiyeny truda i profpatologii v khimicheskoy i mashinostroitel'noy promyshlennosti. (Questions on Work Hygiene and Occupational Pathology in the Chemical and Mechanical Engineering Industries). Reports of the 14-18 June 1966 Scientific Session of the Institute, Khar'kov, 1966, 104-106.

Comprehensive clinical examination of workers (annealers, solderers, television station workers) revealed functional changes in relation to a number of systems in the organism. The earliest and most regular shifts were those in the functional condition of the nervous system. This was exhibited as increased fatigue, asthenia, instability of vegetative reactions, disturbed reflexes and coordination, emotional disturbances, changes in the endocrine profile, etc.

Gorbonosova, N. B. The State of the Health of Ship Radio Operators, Exposed to the Effect of a High-frequency Electromagnetic Field. Collection: Materialy nauchnoy konferentsii po voprosy gigiyeny vodnovo transporta (Material from the Scientific Conference on Water Transportation Hygiene). Moscow, 1964, p. 27-28.

For characteristics of the state of the health of ships radio operators, the author analyzed the health-center cards of the yearly examination of crews of the Baltic State Steamship line for three years. The author established that ship radio operators ailments were primarily diagnosed as diseases of the cardio-vascular system and eyes and functional diseases of the CNS. /192

Gorbonosova, N. B. Some Functional Shifts in Ship Radio Operators Exposed to a Radio-frequency Electromagnetic Field During Voyages. Collection: Gigiyena truda i biologicheskoye deystviye electromagnitnykh voln radiochastot (Work Hygiene and the Biological Effect of Radio-frequency Electromagnetic Waves). Collection of Material from the 3rd All-union Symposium, Moscow, 1968, p. 31-32.

The author studied working conditions related to radio transmitting equipment operating in a range of frequencies from 100 kc to 30 Mc on ships where radiation sources were open feeder lines, the antenna switches, and inadequately screened transmitters. The intensity of a high-frequency field at the working site was from 20 to 100 V/m for SW, and from 150 to 750 V/m for medium waves. Studies were made of body temperature, pulse rate, arterial pressure, and the latent period to a sound, light, and heat stimulus.

It was found that the average increase in the temperature of the body and skin is directly dependent on the field intensity, as well as on the duration of irradiation. Data obtained indicate that ship radio operators display functional damage to thermal regulation and basic nerve processes, /193 primarily the inhibitory process.

Gordon, Z. V. Voprosy gigiyeny truda i biologicheskovo deystviya electromagnitnykh poley sverkhvysokikh chastot (Questions of Work Hygiene and the Biological Effect of Superhigh Frequency Electromagnetic Fields). Moscow, 1966.

A monograph reflecting the present state of the problem on a physical-hygiene, clinical-physiological and experimental plane.

Gordon, Z. V. Questions of Work Hygiene and the Biological Effect of Radiowaves of Various Ranges. Vestnik AMN SSSR, 7, 1964, 42-49.

In the hygienic evaluation of working conditions, it is necessary to consider the character of the field in which the worker is located, the character of the radiation (constant or pulsed), the possibility of radiowaves being reflected from the floor, ceiling, and metal surfaces. Protective means against radio-frequency electromagnetic waves led either to radical measures to make the work healthy or to significantly lowering radiation intensity. In an analysis of biological reactions developing as a result of the chronic action of radiowaves, and especially microwaves of non-thermal intensity, the predominant importance of changes in the CNS must be emphasized and their mediating effect on various systems and functions of the organisms. It can be assumed that radiowaves affect the CNS both directly on the nerve cells of the brain and reflexively — /194 by the transmission of impulses from the receptors. A decisive role can also be assigned to the neuro-humoral factors; the biological effect of radio-frequencies decreases when wavelengths are increased. The reactivity of an organism under the effect of radio-frequency EMW can depend not only on the intensity, duration of radiation and wave range, but also on other conditions: the initial functional state of the organism, the influence of subsidiary factors, etc.

Gordon, Z. V. Questions on Work Hygiene Related to the Effect of a SHF-field. Zhurnal gigiyena truda i professional'nye zabolevaniya, No. 6, 1958, pp. 14-18.

Works related to the possible action of centimeter waves can be divided into 4 groups: 1) Works on the regulation, construction, and testing of radar stations in factories. Measurements in various sections of the shop have shown that radiation intensity can reach 1 meter/cm$^2$ and when radiation is directed to these parts — several mW/cm$^2$. It is necessary to develop protective means. 2) Works on testing and constructing individual HF units of the stations. The sources generating SHF are magnetrons. The testing process of magnetrons entails a comparatively low radiation intensity in the working sites (tenths of a mW/cm$^2$). This kind of radiation can be eliminated by screening the stand with a chamber with an absorbant covering.

3) Works on testing radar stations beyond the premises of the shop. It is best to place the station so that the incident flow of energy waves will not hit the work site. /195

4) Works conducted in Scientific Research Institute (NII) laboratories. It is necessary to use protective means in the form of equivalent power absorbers and shielding chambers.

The author notes some reduction in the excitability of the olfactory and optical analyzers in workers building radar stations as the time they are influenced by centimeter waves increases. Shifts were noted in relation to the cardiovascular system — hypotension, bradycardia, myocardial dystrophy. The systematic action of low-intensities leads to functional damage to the CNS. Studies on animals under chronic radiation with low intensity centimeter waves (to 10 mW/cm$^2$) revealed the predominance of inhibitory processes in the CNS of rats, and disturbance of the conditioned-reflex activity in them, which is also verified by pathomorphological changes in the form of damage to interneural connections of the cerebral cortex.

Gordon, Z. V. The Effect of Microwaves on the Level of Blood Pressure in Experiments on Animals. Collection: O biologicheskom deystvii electromagnitnykh poley radiochastot. (On the Biological Effect of Radiofrequency Electromagnetic Waves). Works of the Laboratory of Radiofrequency Electromagnetic Waves, Institute of Work Hygiene and Occupational Diseases, AMN SSSR. Issue 2, Moscow, 1964, pp. 57-60.

It was established that the characteristic reaction of the vascular system to the influence of microwaves is a hypotensive effect. The extent this is expressed and the time it develops depends on the wave range. The most pronounced and earliest developing decrease of blood pressure is noted in radiation with millimeter and 3-centimeter waves; 10 centimeter and decimeter waves cause a 2-phase course of the reaction. /196

Gordon, Z. V. and V. V. Yeliseyev. Means of Protection Against SHF Radiation and their Effectiveness. Collection: O biologicheskom deystvii elektromagnitnykh poley radiochastot (On the Biological Effect

of Radio-frequency Electromagnetic Fields). Works of the Laboratory of Radio-frequency Electromagnetic Fields, Institute of Work Hygiene and Occupational Diseases, AMN SSSR. Issue 2, Moscow, No. 1964, pp. 151-158.

Different types of screens and devices are suggested, taking into account the characteristics of technological processes. The screens and devices considered provide protection for worker personnel and create a protective strength of 10-60 dB.

Gordon, Z. V., Ye. A. Lobanova, and M. S. Tolgskaya. Some Data on the Effect of Centimeter Waves. (Experimental Studies). Zhurnal gigiyena i sanitariya, 12, 1955, pp. 16-18.

The authors note that the considerable intensity of the radiation of 10-centimeter waves (PPM-40 mW/cm$^2$, in 15 minute exposure, and 110 mW/cm$^2$ in 5 minute exposure) does not have an inhibitory effect on the weight of rats. When radiation intensity is increased to 110 mW/cm$^2$, weight gain /197
in test animals decreased markedly.

Results of histopathological studies of test animals indicate the presence of moderate degenerative and proliferative processes in the nervous system and in the internal organs, increasing when radiation intensity is increased.

Gordon, Z. V. and N. D. Khramova. A Study of Working Conditions of Operators of Radio-relay Communication Lines. Collection: O biologicheskom deystvii elektromagnitnykh poley radiochastot (On the Biological Effect of Radio-Frequency Electromagnetic Fields). Works of the Laboratory of Radio-frequency Electromagnetic Fields, Institute of Work Hygiene and Occupational Diseases, AMN SSSR, Issue 3, pp. 22-25.

Results of studying the working conditions of operators revealed more favorable conditions than in other forms of using SHF equipment.

Gordon, Z. V., P. P. Fukalova, I. A. Kitsovskaya, A. N. Bereznitskaya, and A. A. Pan'kin. Eksperimental'noye izucheniye biologicheskov deystviya elektromagnitnkyh voln radiochastot malykh intensivnostey. Gigiyena truda /198
i biologicheskoye deystviye elektromagnitnykh voln radiochastot. (The Experimental Study of the Biological Effect of Low-intensity Radio Frequency Electromagnetic Waves. Work Hygiene and the Biological Effect of Radio-frequency Electromagnetic Waves). Moscow, 1968.

With prolonged exposure to radiation (4 hours) of microwave (MCW) and USW ranges (intensity of 250 μ W/cm$^2$ and 12 V/m) the resistance of the animals decreases, a reduction in weight is noted, as well as a decrease in blood pressure, weakening of the inhibitory process and a decrease in excitability.

Certain changes were revealed in studying the influence of the MCW range (intensity of 250 μ W/cm$^2$) on the reproductive ability of mice and the development of offspring.

Gordetskaya, S. F. and M. A. Lobova. Some distant results of the biological effect of SHF-fields. Collection: Gigiyena truda i biologicheskiye deystviye elektromagnitnykh voln radiochastot (Work Hygiene and the Biological Effect of Radio-frequency Electromagnetic Waves). Moscow, 1968, pp. 41-42.

Remote aftereffects of the effect of SHF-radiation (20 mW/cm$^2$) on the animal organism are revealed, exhibited in a change in functional indices of sex organs in succeeding generations (especially in the 2-3 generations) disturbance in the estrous cycle, a reduction in fertility and the number of offspring, an increase in the number of still births and abnormalities.

Grigor'yan, D. G. A Study of Proteins in the Blood Serum and Heart Muscle of Animals after the Effect of Microwaves. Voprosy kurortologii, fizioterapii i lechebnoy fizkul'tury No. 1, 1969, p. 52-55. I - UHF, HF and SHF action.

Under the influence of MSW, the albumin content is reduced, but the volume of β and γ globulins increases. The ratio of protein fractions in heart muscles changed more markedly with radiation at a PPM of 40 mW/cm$^2$ in comparison with 6 mW/cm$^2$. /199

Drogichina, E. A. On the Clinical Treatment of the Chronic Effect of SHF on the Human Organism. Collection: O biologicheskom deystvii sverkh vysokikh chastot (On the Biological Effect of Superhigh Frequencies). Works of the Institute of Work Hygiene and Occupational Diseases, AMN SSSR, Vol. 1, Moscow, 1960, p. 29.

The author noted, in those who worked with SHF generators, slow activity on the EEG, while the alpha-rhythm was maintained, which, according to the author, is characteristic of the diencephalic syndrome.

Drogichina, E. A., M. N. Sadchikova, D. A. Ginzburg, and N. A. Chulina. Some Clinical Manifestations of the Chronic Effect of Centimeter Waves. Gigiyena truda i professional'nye zabolevaniya, I, 1962, pp. 28-34.

Bioelectric changes develop when other indices show no reaction.

Dronov, I. S., A. D. Kiritseva, and L. A. Seradskaya. The Effect of Electromagnetic Fluctuations in the SHF Range on the Formation of Antibodies in Rabbits. Collection: Gigiyena truda i biologicheskoye deystviye elektromagnitnykh voln radiochastot (Work Hygiene and the Biological Effect of Radio-frequency Electromagnetic Waves). Moscow, 1968, pp. 46-48.

Immunological shifts in the organism of animals indicate that electromagnetic fluctuations in the SHF range at a PPM of 50 μ W/cm$^2$ suppress antibody-formation in rabbits under chronic radiation in the immunization of animals. /200

Dumanskiy, Yu. D., L. I. Krasiliskaya, L. K. Yershova, and L. G. Andriyenko. On the Question of the Hygienic Evaluation of a Radio-frequency Low-intensity Short-wave Electromagnetic Field. Collection: Gigiyena truda i biologicheskoye deystviye elektromagnitnykh voln radiochastot (Work Hygiene and the Biological Effect of Radio-frequency Electromagnetic Waves). Collection of Material from the 3rd All-union Symposium, 24-28 June 1968, pp. 48-50.

The authors studied the effect of WS on the organism of animals. They showed that an intensity from 0.4 to 50 V/m for 5 months depresses phagocytic activity of the blood and leads to changes in relation to the nervous system, ketosteroid content, RNA, DNA, and the morphological condition of the blood.

Yermakov, Ye. V. On the Mechanism of Developing Astheno-vegetative Disturbances under the Chronic Effect of a SHF-field. Voyenno-meditsinskiy zhurnal. 3, 1969, pp. 42-44. Bibliography.

The author associates the causes of asthenovegetative disturbances under the chronic effect of a SHF field with the predominant injury of diencephalic structures. He is led to this conclusion by the results of electrophsiological research — EEG changes in recordings from the base of the brain, indicating damage to subcortical structures. Damage to the hypothalamus area involves the endocrine system of the organism in the process. /201

Zakharov, I. V. The Effect of Prolonged SHF Radiation on the Functional State of Leukocytes. Voyenno-meditsinskiy zhurnal, 3, 1969, p. 87.

Three phases were detected in changes in the functional state of leukocytes in peripheral blood when a man is irradiated in a weak SHF-field (peroxidase activity, glycogen content in leukocytes). The first phase — stimulation of the functional activity of leukocytes; the second — its depression, which indicates a cumulative effect; the third — the absence of changes, which the author treats as adaptation to weak SHF fields (1-5 μ W/cm$^2$).

A change in the functional state of leukocytes in peripheral boood is evidently one of the manifestations of a general non-specific reaction of the organism to SHF radiation.

Zenina, I. N. The Effect of Pulsed SHF Electromagnetic Fields on the Central System in Brief and Prolonged Radiation. Collection: O biologicheskom deystvii elektromagnitnykh poley radiochastot. (On the Biological

Effect of Radio-frequency Electromagnetic Fields). Works of the Laboratory of Radio-frequency Electromagnetic Fields, Institute of Work Hygiene and Occupational Diseases, AMN SSSR, Issue 2, Moscow, 1964, p. 26.

The predominance of EEG changes was established under the effect of pulse SHF fields with respect to quickening of the rhythm, greater sensitivity to decimeter* waves was detected in comparison to decimeter* waves. It was shown that chronic radiation has an epileptogenic effect. /202

*Translator's Note: Obvious misprint in foreign text.

Ivanov, A. O. and B. A. Chukhlovin. The Functional State of Leukocytes under the Effect of SHF Radiation on the Organism. Collection: Gigiyena truda i biologicheskoye deystviye elektromagnitnykh voln radiochastot. (Work Hygiene and the Biological Effect of Radio-frequency Electromagnetic Waves). Collection of Material from the 3rd All-union Symposium. 24-28 June 1968. Moscow, 1968, pp. 62-63.

In irradiated volunteers the brief action of USW and MW (1.95 M and 10 cm) depressed phagocytic activity of neutrophils with simultaneous limitation of their mobility and a decrease in their content of glycogen and oxidizing enzymes (pyroxidase and cytochromoxidase). Changes in the phagocytic activity of the blood had a phase character. Five minutes from the start of radiation, activation was observed; after 30-60 minutes — depression.

Kadaner, Ya. D., S. V. Pantyukhina, and E. I. Yelovey. A Study of Ataxia in Vitro by Proteolytic Enzymes of Meat and Fish Proteins After they were Heated at Superhigh Frequency. Voprosy pitaniya, Vol. 27, No. 6, 1968, 3 UHF, HF and SHF — Application No. 42063. 44 No. 5773. Entire Book also in TsTB 21, IV, 1969.

Heat energy is released immediately in the treated product simultaneously throughout its mass. This causes the products to be cooked at a high speed. It is established that there are no essential differences in the rates of ataxia in vitro by the proteolytic pepsin-trypsin enzyme system in proteins of cod, prepared in SHF equipment and heated by ordinary means. /203

Kalyada, T. V. The Biological Effect of Constantly Generated UHF Electromagnetic Waves on the Human Organism. Collection: Gigiyena truda i biologicheskoye deystviye elektromagnitnykh voln radiochastot (Work Hygiene and the Biological Effect of Radio-frequency Electromagnetic Waves). Collection of Material of the 3rd All-union Symposium, 24-28 June 1968, Moscow, 1968, pp. 63-65.

Kalyada, T. V. and V. A. Orlov. The Hygiene Characteristics of the Radiation Intensity of Workers with SW and Medium Wave (MW) Transmitters. Collection: Voprosy gigiyeny truda i vliyaniye elektromagnitnykh poley no organism chelovaka (Questions of Work Hygiene and the Effect of Electromagnetic Fields on the Human Organism). Leningrad, 1968, pp. 20-31.

Field intensity depends on a number of factors: the characteristics of the transmitters, the work regime, the type of antenna, the energy transmission line system, generated power and the degree to which the radiation sources are screened.

The radiation intensity affecting radio operators using high frequency energies can be reduced by effective screening of separate stages of the transmitter, filters and feeder lines.

Kalyada, T. V. and V. N. Nikitina. Hygienic Evaluation of SHF Radiation on Commercial Ships and in ERNK. Collection: Aktyal'nye voprosy gigiyeny truda i professional'noi patologii (Current Questions of Work Hygiene and Occupational Pathology). Conference Materials, Riga, 1968, pp. 113-115. /204

On the decks and superstructures of marine transport and passenger ships, the PPM is from one to hundreds of $\mu$ W/cm$^2$. The main sources of microwave radiation are the antennae of the radar station equipment on the upper bridge, pedestals, or masts at various heights. Two radar stations are installed on each multi-tonnage ship for far and near circular scanning (Donets, Don, Stvor). Proper location and selection of the height of the radar antennae will ensure dead space on the decks and superstructures. Placing the antennae lower than 7 m creates a large PPM on the deck.

Klyachina, K. N., I. Ye. Okonivnikova, E. A. Kalinina, et al. Experimental Study of the Chronic Effects of 10 cm, Superhigh-frequency Electromagnetic Fields in Combination with Soft X-rays. Collection: Voprosy gigiyeny, profpatologii i promyshlennoy toksikologii (Questions of Hygiene, Occupational Pathology and Industrial Toxicology). Material of the XIV Scientific Session and Symposium on Manganism, Sverdlovsk, 1966.

In the chronic combined effect of SHF and Ro", a number of functional shifts and morphological changes are observed in organs and systems, developing after different periods of radiation.

Results of the studies indicate that the chronic combined effect of SHF and Ro", at radiation intensities close to industrial intensities, caused a number of functional shifts and morphological changes in test animals. These changes, in most cases, had the character of regulatory disturbances, which is confirmed by their phase nature and reversability. The organs and systems recovered their disturbed functions at an unequal rate, and in a number of cases even a 2-month recovery period was inadequate. From uniform changes in different organs and systems, developing in animals under the influence of the chronic combined effect of SHF and Ro", it can be concluded that in the majority of cases they are caused by the unique effect of both radiation factors. But even when the isolated effect of SHF and Ro" caused the same reactions in organs and systems, the reaction to the effect of X-radiation in the majority of cases was more pronounced than that to the effect of SHF. /205

Karamyshev, V. B. Physiological-hygienic Characteristics of the Working Conditions of Television and Radio Station Personnel. Collection: Voprisy gigiyeny truda i profpatologii v khimicheskoy i mashinostroitel' noy promyshlennosti (Questions of Work Hygiene and Occupational Pathology in the Chemical and Mechanical Engineering Industries). Reports of the Scientific Session of the Institute. 14-18 June 1966, Kharkov, 1966, pp. 106-107.

Physiological observations made under industrial conditions on television and radio station staffs showed that slight shifts in the state of the CNS occur during work shifts. This was manifest in a slight change in optic-motor and a rise in motor reactions, elevation of olfactory thresholds, curtailment of chronaxy. To protect personnel from the effect of electromagnetic radiation, the author recommends additional screening of the transmitters or operating the transmitters by remote control. /206

Karam'shev, V. B. Izmeneniya v organizme zhivotnykh pri deystvii elektromagnitnykh poley metrovovo diapazona i voprosy gigiyenicheskovo normirovaniya (Changes in the Organism of Animals under the Effect of Metric Electromagnetic Fields and Questions of Hygienic Standardization). Material of the Ukranian Republic Conference of Industrial Health Inspectors and Scientists. Session of Kharkov Institute of Work Hygiene and Occupational Diseases, Kiev, 1968, pp. 128-130.

In the 48 Mc range (first USW television channel) on the basis of a number of experimental studies, with threshold values of 200 V/m and 1 a/m, the MPL of radiation for frequencies of 30-50 Mc is recommended as 10 V/m for the electric component, and 0.3 A/m for the magnetic component.

Karamyshev, V. B., N. N. Goncharova, and N. V. Maksimenko. Some Data on the Effect of Electromagnetic Fields of the USW Range on Animals. Collection: Gigiyena truda i biologicheskoye deystviye elektromagnitnykh voln radiochastot (Work Hygiene and the Biological Action of Radio-Frequency Electromagnetic Waves). Collection of Material of the 3rd All-union Symposium. 24-28 June 1958. Moscow, 1968. /207

A study of the effect of USW (48 Mc) on the level of blood pressure showed a two-phase course of the reaction under the effect of an electric field (800 V/m) and a reduction in pressure under the effect of a magnetic field (7 A/m). Other indices also indicated the multi-directional character of the changes: an increase in sugar content under the effect of the electric field and a decrease in the magnetic field. Total protein increased because of an increase in the amount of globulin fractions under the influence of the electric magnetic field.

Kirchev, K., P. Yeftinov, and S. Sivchev. Nekotorye eksperimental'nye dannye o vliayanii elektricheskovo polya UVCh na nadpochechniki. Voprosy fizioterapii i kurortologii. (Some Experimental Data on the Effect of an UHF Electric Field on the Adrenals. Problems of Physiotherapy and

Health Resorts). Moscow, 1959, pp. 81-88.

Under the influence of a UHF field, the weight of the adrenals increases as a result of hyperplasia and pronounced hypertrophy of cellular elements.

Kitsovskaya, I. A. The Effect of Centimeter Waves of Various Intensity on the Blood and Blood-forming Organs of White Rats. Gigiyena truda i professional'nye zabolevaniya, No. 6, 1969, p. 14.

Studies of the blood in radiating animals with 10 centimeter waves of large and small intensity indicate changes in the condition of the blood. /208
Reactions with respect to white blood cells appeared as a change in the leukocytic formula (an increase in the number of segmented-nucleus neutrophils and a decrease in lymphocytes) and a tendency toward leukopenia. In irradiation with greater intensities (100.40 $mW/cm^2$) changes in the leukocytic formula are noted after the first radiation sessions, and under the effect of low intensities — only after several months. Under the action of high intensities, a decrease is also observed in the number of erythrocytes with a subsequent increase in the number of reticulocytes. A study of the effect of radiation on blood formation indicates hyperplasia in the erythroblastic part of bone marrow. In the white part, changes appear as a slight reduction in segmented-nucleus neutrophils.

Kitsovskaya, I. A. The Effect of Radiation of Decimeter, Low-intensity Radiowaves on the Inhibition Process. Gigiyena truda i biologicheskoye deystviye elektromagnitnykh voln radiochastot (Work Hygiene and the Biological Action of Radio-frequency Electromagnetic Waves). Moscow, 1968, p. 72.

Results of the studies indicate that radiation at low intensities affects both kinds of inhibition, namely internal and external; it also reduces excitability and decreases the ability of the CNS neurons to function.

Kitsovskaya, I. A. The Influence of Low-intensity Microwaves on Indices Characterizing the State of Cholinergic Processes. Gigiyena truda i /209
biologicheskoye deystviye elektromagnitnykh voln radiochastot. (Work Hygiene and the Biological Effect of Radio-frequency Electromagnetic Waves). Moscow, 1968, p. 71.

The author notes the disturbance of cholinergic processes in rats under the influence of radiation. These changes are expressed in the reduced activity of cholinesterase in the large hemispheres and stem sections of the brain, an increase in the amount of acetylcholine in the large hemispheres, a decrease of SH-groups in the stem section of the brain, an increase in the amount of N ions and a decrease of K ions in the large hemispheres and stem section of the brain.

Kitsovskaya, I. A. The Effect of Decimeter Radiowaves on the Functional State of Sections of the Central Nervous System. O biologicheskom deystvii elektromagnitnykh poley radiochast (On the Biological Effect of Radio-frequency Electromagnetic Fields). Moscow, 1968, p. 71.

Results of studies of the effect of radiation on convulsive attacks in rats, caused by the injection of pharmacological substances with different points of application in the CNS, indicate that this factor affects certain structures of the CNS, but their sensitivity to radiation is not the same.

Radiation decreases the excitability of the motor zone of the cerebral cortex and subcortical structures, blocks the excitable systems of the segmental apparatus, and depresses N-cholinoreactive systems. The midbrain and the lymphatic system are not very sensitive to this factor, and the M-cholinoreactive systems are almost completely insensitive to it. /210

Kitsovskaya, I. A. The Effect of Radiowaves of Various Ranges on the Nervous System (Sound Stimulation Method). O biologicheskom deystvii elektromagnitnykh poley radiochastot (On the Biological Effect of Radio-frequency Electromagnetic Fields). Moscow, 1968, p. 81.

The influence of radiowaves of non-thermal intensity in SHF, UHF, and HF ranges on the nervous system of rats, sensitive to sound stimulation, leads to significant shifts in the basic nerve processes of the rats. These shifts are expressed in decreased sensitivity of the animals to sound stimulations and, principally, in weakening the reaction, change in excitability, extension of the latent period, extension of the first wave of excitement and a shortening of the inhibition period, or a complete absence of a reaction to sounds. This all indicates a lowering of excitability, a weakening of the processes of excitation and inhibition. Changes in the sonic reaction of rats which develop under the influence of various ranges have a unidirectional character. However, there are certain features which are evidently based on differences in the distribution and absorption of energy in the organs and tissues.

Komarova, L. A. Changes in Arterial Pressure and External Respiration in Animals Under the Influence of a Superhigh Frequency Electromagnetic Field (Microwaves). Voprisy kurortologii, 6, 1968, 503-506. Bibliography.

The author used high intensity radiation (0.4 and 0.13 $W/cm^2$) for 10 minutes in various radiation locations. It was revealed that the greatest /211 changes in blood pressure, vascular reflexes, and external respiration are noted when the dorsal surface of the head is irradiated. The author suggests that these changes develop because of stimulation of skin receptors (reflexive reaction), but he does not deny the direct effect of the SHF field on the brain. Under the effect of MCW, the state of the vegetative centers of the brain are changed, which affects the regulatory functions of the CNS in relation to the circulatory and respiration systems. This

is indicated by increased arterial pressure, more frequent respiration at the moment the head is irradiated, and a change in pressure reflexes after the action. When areas of the neck are irradiated, changes in the functional state of the receptors in the area of the carotid sinus are expressed in the decreased level of arterial pressure, by a lower pressure effect, and by vascular reflexes to pressure on the irradiated carotid artery. This does not occur in the case of irradiation of the abdomen. Evidently the SHF field has less effect on the solar plexus, possibly because MSW energy is absorbed by organs in the abdominal cavity or because of the low sensitivity of this reflexogenic zone to MCW.

Kruglikov, R. I. and M. P. Troyanskiy. On the Question of the Physiological Reactions of the Central System to the Effect of Superhigh Frequency Electromagnetic Fluctuations. Collection: Fiziologicheskiye mekhanismy individualnoy adaptatsii (Physiological Mechanisms of Individual Adaptation). Novosibirsk, 1967, p. 124. /212

It is established that the non-thermal action of micro-waves with a PPM of 3-4 $\mu$ W/cm$^2$ lessens primary and later secondary responses.

Kulakova, V. V. The Effect of 10 cm. Waves on Special Forms of Appetite and the Electrolytic Composition of the Blood and Urine in Rats. Collection: O biologicheskom deystvii elektromagnitnykh poley radiochastot (On the Biological Action of Radio-frequency Electromagnetic Fields). Works of the Laboratory of Radio-frequency Electromagnetic Fields, Institute of Work Hygiene and Occupational Diseases, AMN SSSR, Moscow, 1968, pp. 112-119.

Studies were made on 40 white rats. The animals were divided into eight groups (five animals in each). For two months, four groups were exposed to daily 15-minute radiation with 10 cm waves at an intensity of 40 mV/cm$^2$. The remaining four groups were controls.

Glucose was introduced into the diet of the animals of the test series (I, II and III groups) in a solution of salts (KCl, NaCl, $CaCl_2$).

The electrolytic balance was determined for the animals in test group IV. A special dialyzing fistula was used for this.

In all three series of tests, under the influence of radiation the authors noted predominant change in salt appetite. Indices characterizing water appetite were noted as more stable.

Data characterizing ion shifts in the dialysate and urine suggest that, in the organism of the animal under the influence of a SHF field, a change occurs in the electrolytic composition which is not the same at different periods of chronic action. Considering that in animals under ordinary conditions there is a certain correlation between the composition of the internal medium and the appetite, the existence of a similar /213

dependence can also be assumed in animals subjected to the effect of a SHF field. Changes in sodium, calcium, and potassium appetites can be related to the ability of the animals to restore disturbed homeostasis by changing their consumption of salts. The authors observed this dependence in the case of sodium and potassium appetites: an increase in the amount of Na in the internal medium reduced the sodium appetite. On the other hand, reducing K in the dialysate increased potassium appetite. No definite correspondence between the calcium appetite and the electrolytic composition was noted.

Kulikovskaya, Ye. L. and Yu. A. Osipov. Electromagnetic Fields in Work Rooms with High-frequency Heating. Gigiyena truda i profzabolevaniya, No. 6, 1960, pp. 3-7.

To lower the field intensity in HF equipment in dielectric heating, the authors recommend unit screening of the equipment.

Liman, A. D. and G. I. Nemtseyev. Biologicheskaya aktivnost' setchatki i provodimost' zritel'no-nervnovo puti u rabotayushchikh v usloviyakh vozdestviya elektromagnitnykh poley diapozona UVCh. (Biological Activity of the Retina and the Conductivity of the Optical-nerve Path in Those Working under the Effect of UHF Electromagnetic Fields). Material of the Ukrainian Republic Conference of Industrial-health Inspectors and Scientists. Session of Kharkov Scientific Research Institute of Work Hygiene and Occupational Diseases. Kiev, 1968, pp. 131-133. /214

For individuals subjected to the influence of a UHF field for a long time, shortening of the latent period of the electrical reaction of the retina to light stimulation is characteristic, with a normal time for the stimulation along the optical-nerve pathway. An increase is noted in corneal-retinal potential. This could indicate a disturbance of centrifugal regulation of the parameters as a result of the chronic effect of an EMF on subcortical structures sensitive to it.

Liman, A. D. and G. I. Nemtseyev. Electrophysiological Studies of the Organ of Sight in Those Working Under the Effect of UHF Electromagnetic Fields. Collection: Gigiyena truda i biologicheskoye deystviye elektromagnitnykh voln radiochastot (Work Hygiene and the Biological Action of Radio-frequency Electromagnetic Waves). Collection of Material of the Third All-union Symposium. 24-28 June 1968, Moscow, 1968, pp. 86-87.

Electrophysiological studies of the organ of sight (ERG) indicate that ERG might be used in occupational pathology for early recognition of functional shifts in the CNS in individuals exposed to the effect of radio-frequency electromagnetic fields.

Lifshits, N. N. Conditioned-reflex Activity of Dogs Under the Local UHF Effect on Certain Zones of the Large Hemisphere Cortex. Biofizika, 2, 2, 1957, pp. 197-208, 378-387. /215

The effect of UHF in many respects depends on the initial condition of the organism. Particularly non-uniform is the effect of the UHF field on the conditioned-reflexes of animals with different kinds of higher nervous activity (VND). In dogs with a strong VND, the effect of UHF fields on the cerebellum disturbed the function of the cortex, and reduced conditioned reflexes only in the sound analyzer; in dogs with a weak VND, disturbances were related to various analyzers.

Since it has a penetrating effect, the UHF field can affect the nervous system not only by reflex means, but also by direct action.

Lobanova, Ye. A. Changes in Conditioned-reflexes of Animals Under the Influence of Microwaves of Various Ranges. Collection: O biologicheskom deystvii elektromagnitnykh poley radiochastot (On the Biological Effect of Radio-frequency Electromagnetic Fields). Moscow, 1964, pp. 13-19. Works of the Institute, Issue 2.

Two phases are determined in changes in conditioned reflexes during radiation: an increase in the excitability of the central nervous system, and a weakening of active inhibition, and a second phase of weakened excitation, and the development of external inhibition.

Lobanova, Ye. A. Survival and Development of Animals at Various Intensities /216
and Duration of SHF Action. Collection: O biologicheskom vozdeystvii sverkhvysokikh chastot (On the Biological Effect of Superhigh Frequencies). Works of the Institute of Work Hygiene and Occupational Diseases, AMN SSSR. Issue 1, Moscow, 1960, pp. 61-65.

Resistance of the animals to physical load (swimming) was significantly decreased after momentary radiation.

Lobanova, Ye. A. The Effect of the Chronic Action of Pulsed and Constant Ten-centimeter Waves on the Conditioned-reflexes of White Rats. Zhurnal Gigiyena truda i profzabolevaniya. No. 10, 1966, pp. 7-11.

The author studied the reaction of the CNS to the chronic influence of 10-centimeter microwaves, generated by pulsed and constant means, with the same intensity and length of radiation time. He concluded that:

1 - the character and type of the changes which developed under the influence of pulsed and constant microwaves are basically the same.

2 - When animals are irradiated with pulsed microwaves, in comparison with constant microwaves a more pronounced reaction of the CNS is noted in the initial period (from the 1st to the 19th session).

3 - With constant microwave radiation, shifts in conditioned reflexes intensify toward the end of chronic radiation (from 81st to 99th session).

Lobanova, Ye. A. and A. V. Goncharova. The Effect of Radio-frequency Electromagnetic Fields in the 191 and 155 Mc Ranges on the Conditioned Reflexes of Animals. Collection: O biologicheskom deystvii elektromagnitnykh poley radiochastot (On the Biological Effect of Radio-frequency Electromagnetic Fields). Works of the Institute, Issue 3, Moscow, 1968, pp. 76-80. /217

The material presented indicates that chronic irradiation of animals for 4.5 months in an EMF with UHF waves of low intensity does not have a marked effect on their conditioned reflexes.

Lobanova, Ye. A. and Z. B. Gordon. The Study of Olfactory Sensitivity in Persons Exposed to SHF. Collection: O biologicheskom vozdeystvii sverkhbysokikh chastot (On the Biological Effect of Superhigh Frequencies). Works of the Institute of Work Hygiene and Occupational Diseases, AMN SSSR, Issue 1, Moscow, 1960, p. 52.

In examining persons who work with SHF generators, a decrease in olfactory sensitivity was revealed, the character of which is determined by the conditions and stage of the work. The decrease in olfactory sensitivity in a group of evidently healthy individuals might serve as one of the indices of early signs of the effect of SHF.

Lobanova, Ye. A. and M. S. Tolgskaya. Changes in Higher Nervous Activity and Inter-neuron Connections in the Cerebral Cortex of Animals Under the Influence of SHF. Collection: O biologicheskom vozdeystvii sverkhvysokikh chastot (On the Biological Effect of Superhigh Frequencies). Works of the Institute, Issue 1, Moscow, 1960, pp. 69-74.

Disturbed conditioned reflexes in animals and changes detected in inter- /218
neuron connections of the cerebral cortex indicate the non-thermal effect of SHF with an intensity of 10 $mW/cm^2$ which does not cause increased body temperature.

Loshak, A. Ya. Radio-frequency Radiation of Airplane Radio Equipment as a Health Factor. Zhurnal Gigiyena truda i professional'nye zabolevaniya, 5, 1968, pp. 15-18.

The use of airplane radio equipment causes brief radiation of the on-board radio operator and in isolated cases, other crew members from SW and MW fields with an intensity from one to several hundred V/m and from USW of less than 10 V/m, because of open feeder lines. The intensity of radiation depends on the design and mounting of the equipment, the components, and their position.

Physiological studies of on-board radio operators and other crew members, as well as data on their sick rate, did not reveal pronounced changes.

Loshak, A. Ya. and V. L. Chilinskiy. Work Conditions in Radio Transmission Centers and in Civil Aviation Airplane Radio Equipment Repair Shops. Collection: Gigiyena truda i biologicheskoye deystviye elektromagnitnykh voln radiochastot (Work Hygiene and the Biological Effect of Radio-frequency Electromagnetic Waves). Collection of Material of the Third All-union Symposium, 24-28 June 1968, Moscow, 1968, pp. 99-102.

Hygienic and clinical-physiological studies of operators established the relative stability of changes which developed (no progression with increased work experience and, at the same time, poor reversibility of the observed changes even when contact with high-frequency radiation is terminated). /219

Lysina, G. G. and S. B. Rappoport. On the Question of Hemodynamic Regulation Under the Influence of SHF Electromagnetic Radiowaves (Clinical-experimental Studies). Collection: Gigiyena truda i biologicheskoye deystviye elektromagnitnykh voln radiochastot (Work Hygiene and the Biological Effect of Radio-frequency Electromagnetic Waves). Collection of Material of the Third All-union Symposium, 24-28 June 1968, Moscow, 1968, pp. 108-110.

On the basis of clinical observations and morphological research, it can be concluded that hemodynamic disorders depend not so much on the direct effect of radiation on the cardio-vascular system, as on damage to the structure and function of regulatory systems of the organism (CNS, endocrine system).

Maksimenko, N. V. Protective Measures in Working with USW Transmitters in Television and Radio Stations. Collection: Voprosy gigiyeny truda i profpatologii v khimicheskoy i mashinostroitel'noy promyshelennosti (Questions of Work Hygiene and Occupational Pathology in the Chemical and Mechanical Engineering Industry). Reports of the Scientific Session of the Institute, 24-28 June 1966, Kharkov, 1966, pp. 104-106.

Effective solutions to protect personnel from electromagnetic radiation are:

1 - Decreasing field strength by increasing the effectiveness of chromium-plating transmitter cabinets and 2 - placing the control panel of the transmitters in a separate screened room-booth. /220

Maksimenko, O. V., N. N. Goncharova, and V. V. Karamyshev. Opty snizheniya napryazhennosti elektromagnitnovo polya v apparatnykh zadakh UKV radiostantsii teletsentrov (Testing Decrease of Electromagnetic Field Intensity in USW Equipment of Television Stations). Material of the Ukrainian Republic Conference of Industrial-health Inspectors and Scientists, Session of Kharkov NII of Work Hygiene and Occupational Diseases, Kiev, 1968, pp. 124-125.

Field intensity in television centers fluctuates from 12 to 450 V/m in transmitters, and 32 V/m at the control panel. To improve working conditions, the authors worked out measures to screen radio transmitting equipment.

Mishchenko, L. I. The Effect of an Ultrahigh Frequency Electromagnetic Field on Carbohydrate Exchange in the Brain of Rats. Byulleten' eksperimental'noy biologii (Byull. ekspl. biol) No. 7, 1969, pp. 56-58. Bibliography.

Under the effect of a field in the UHF range (48 Mc) of non-thermogenic intensity, the amount of lactic and pyruvic acids in brain tissues increased, and the amount of glycogen decreased. These effects depend on field intensity and the duration of its action. We know that the principal substratum of oxidizing processes in the brain, which provide its energy reserves, is glucose. These changes can be directly connected with disturbances to the function of the brain under the effect of a UHF field.

Mishchenko, L. I. Vliyaniye elektromagnitnovo polya UVCh no obmen atsetilcholina v mozgu krys (The Effect of a UHF Electromagnetic Field on Acetylcholine Exchange in the Brain of Rats). Material of the Ukrainian Republic Conference of Industrial-health Inspectors and Scientists. Session of the Khar'kov Institute of Work Hygiene and Occupational Diseases. Kiev, 1968, pp. 135-136. /221

The functional state of the nervous system (NS) is determined to a considerable degree by its level of acetylcholine, as the chemical mediator in the transmission of impulses in CNS synapses. There is also a trophic effect on the NS.

In both thermogenic and non-thermogenic intensities (the latter with prolonged action), the authors note a decrease in the amount of acetylcholine in the brain. The activity of the enzyme acetylcholinesterase is lower in the brain tissues of irradiated animals.

Moskalenko, Yu. Ye. Clinical and Biological Use of SHF Electromagnetic Fields. Collection: Elektronika v meditsine (Electronics in Medicine), Moscow-Leningrad, 1960, pp. 207-218.

The principle of recording exchange variations in biological objects by using radiowaves is based on the difference in the electrical characteristics of living tissues of various structures, for example, blood and dense cells of tissues (muscles, adipose parenchymatous tissues).

The SHF electroplethysmograph method can be used in studying those objects which, when attached to recording equipment, would display changes in

their normal functioning. The principle is based on the relation between a decrease in the power flux in the waveguide and the dimensions of the object. For wide application of these methods, further development and more precise definition of the theoretical bases of HF and SHF electroplethysmography are necessary. /222

Nikogosyan, S. V. Comparative Evaluation of the Effect of Microwaves on Some Aspects of Protein Exchange in Experimental Animals. Collection: O biologicheskom deystvii elektromagnitnykh poley radiochastot (On the Biological Effect of Radio-frequency Electromagnetic Fields). Works of the Institute, Issue 3, Moscow, 1968, pp. 107-111.

Changes in the amount of protein fractions in blood serum, residual nitrogen in the blood, and amino acids in daily urine of irradiated animals can indicate disturbances to the dynamic equilibrium between proteins of the blood and tissues and the increased disintegration of proteins in the tissues.

Changes in the disintegration of proteins in tissues proceeds in two phases. The first phase is characterized by stimulation of dissimilation processes in protein exchange; the second by a certain depression of them.

Nikogosyan, S. V. The Effect of 10-cm Waves on the Amount of Nucleic Acids in the Organs of Animals. Collection: O biologicheskom deystvii elektromagnitnykh poley radiochastot (On the Biological Effect of Radio-frequency Electromagnetic Fields). Works of the Laboratory of Radio-Frequency Electromagnetic Fields, Institute of Work Hygiene and Occupational Diseases, AMN SSSR, Moscow, 1964, pp. 66-67.

It is established that, under the chronic influence of 10 cm waves of low intensity, the amount of RNA in the spleen, liver and brain of animals (rats) decreases. The amount of DNA in the organs did not change. /223

Nikogosyan, S. V. A Study of the Activity of Cholinesterase in Blood Serum and in Organs of Animals Under the Chronic Influence of Microwaves. Collection: O biologicheskom deystvii elektromagnitnykh poley radiochastot. (On the Biological Effect of Radio-frequency Electromagnetic Fields). Moscow, 1964, pp. 43-48.

The author discusses the decreased cholinesterase activity in blood serum under the influence of microwaves, suggesting that radio-frequencies affect the cholinergic processes which are involved in the transmission of nerve impulses.

Nikogosyan, S. V. and I. A. Kitsovskaya. The Altered Activity of Cholinesterase in the CNS of Animals in Various Functional States Under the Influence of Low Intensity Decimeter Waves. Gigiyena truda i professional'nye zabolevaniya, No. 5, 1968, p. 53.

The chronic influence of decimeter waves causes a decrease in the activity of cholinesterase in the CNS of rats. Its effect in the large hemispheres varies depending on the functional state of the CN system (in both ordinary rats and in those sensitive to a sound stimulus, a decrease in the activity of cholinesterase was observed in the large hemispheres and in the brain stem). In rats who are sensitive to sound stimuli, the decrease in cholinesterase activity is more pronounced than in ordinary rats.

Nikonova, K. V. The Effect of a High Frequency Electromagnetic Field on Blood Pressure and Body Temperature in Experimental Animals. Collection: O biologicheskom deystvii elektromagnitnykh poley radiochastot (On the Biological Effect of Radio-frequency Electromagnetic Fields). Works of The Laboratory of Radio-frequency Electromagnetic Fields, Institute of Work Hygiene and Occupational Diseases, AMN SSSR, Issue 2, Moscow, 1964, pp. 61-66. /224

It is established that the HF effect of a high frequency electric field (500 kc) with an intensity of 8000 V/m increases the body temperature of animals by 0.3°C.

In chronic testing conditions at an intensity which does not cause a thermal effect, 1800 V/m and 50 A/m produce a decrease in blood pressure in rats. The hypotensive effect is more pronounced under the influence of a magnetic field with an intensity of 50 A/m.

Nikonova, K. V. The Biological Effects of the Combined Influence of SHF and Soft X-radiation. Gigiyena truda i biologicheskoye deystviye elektromagnitnykh voln radiochastot. Moscow, 1968, pp. 121-123.

The combined effect of the SHF (10 cm) range and soft X-radiation (13.5 keV) at various intensities of both factors was studied. It was established that the biological effect depends on the intensities used and the conditions of the experiment: 1 - radiation with microwaves at an intensity of 40 $mW/cm^2$ did not have a significant effect on the survival of mice irradiated with X-rays at a level of LD 50/30 (3500 R), regardless of whether it preceded X-ray radiation or followed it. With a different sequence of action — first a tolerable roentgen dosage (2500 R), then SHF (100 and 40 $mW/cm^2$), until death by radiation — in the first days, either independent action or antagonism was observed. After a longer period of time, sensitivity to SHF increased. /225

2 - animals were irradiated once with X-rays with a dosage of 2500 R. They were subsequently irradiated with SHF at an intensity of 40 $mW/cm^2$ for 15 minutes a day for 6 weeks; a comparison was made with groups of animals exposed to the effect of X-rays alone or SHF alone, as well as with control groups. Comparison with groups of animals exposed to a "blank" effect showed that changes under the combined effect are more

pronounced than under the effect of each factor individually; the data suggest the presence of synergism in the effect of these factors.

Nikonova, K. V. and P. P. Fukalova. Hygienic Evaluation of Working Conditions and the Effectiveness of Protective Measures in the Induction Heating of Metal Using High-frequency Vacuum-tube Oscillators. Gigiyena truda i profzabolevaniya, No. 3, 1962, pp. 8-13.

A decrease in the intensity of electromagnetic fields is attained by total or unit screening of radiation sources. Both screening methods give good results. /226

Nikonova, K. V. and N. D. Khramova. On the Possibility of Workers with SHF Sources in the Electronic Industry Being Radiated with Soft X-rays. Gigiyena truda i biologicheskoye deystviye elektromagnitnykh voln radiochastot. Moscow, 1968, pp. 123-124.

Measurements of the intensity of soft x-radiation were made in 14 plants in the electronics industry at various stages of the technological process (from the testing of individual units to operating the finished products). Measurements were made by a micro-roentgenometer with a scintillation unit.

Persons working in direct proximity to open modulator and generator units can be exposed to the effect of soft x-radiation.

Sources of x-radiation in SHF equipment can be modulator and generator tubes and HF instruments (magnetrons, klystrons, scanning wave tubes, etc.), operating at a high anode voltage (10-12 k V). The strongest sources of soft x-radiation are modulator tubes. With regard to klystrons, powerful klystrons can generate, depending on the operating anode voltage (to 150 kV and higher), not only soft radiation, but hard x-rays as well. As a rule, these instruments have dependable radiation protection and the radiation intensity beyond the protection does not exceed 0.1 μ R/sec. To prevent irradiation of workers, screening of soft x-radiation sources is necessary; for jobs with open modulator and generator instruments, technological screens must be used. /227

Nikonova, K. V., N. D. Khramova, and N. V. Kartaxhov. Rentgenovskoye izlucheniye v ustanovkakh SVCh. O biologicheskom deystvii elektromagnitnykh poley radiochastot. (X-radiation in SHF Equipment. On the Biological Effect of Radio-frequency Electromagnetic Fields). Moscow, 1968, pp. 12-16.

Persons working with SHF equipment can be subjected to the effect of soft x-radiation when handling open modulator and generator units, and with inadequate screening of the latter.

Soft x-radiation is quite effectively screened by metal sheathing on the SHF equipment cabinet. In isolated cases, additional protection is necessary. In work with open modulator and generator units, technological screens must be used.

Orlova, A. A. On the Clinical Treatment of Changes in Internal Organs Under the Effect of SHF. Collection: O biologicheskom vozdeystvii sverkhvysokikh chastot (On the Biological Effect of Superhigh Frequencies). Works of the Institute of Work Hygiene and Occupational Diseases, AMN SSSR, Issue 1, Moscow, 1960, pp. 36-41.

The effect of SHF on the organism is characterized by a change in the cardio-vascular system, primarily of a vagotonic character.

Osipov, Yu. A., R. N. Vol'fovskaya, T. P. Asakova, et al. On the Question of the Combined Effect of a High-frequency Electromagnetic Field and X-radiation in Industry. Gigiyena i sanitariya, No. 7, 1963, pp. 35-39. /228

After carrying out certain hygienic measures recommended by the institute, women workers in the outgassing evacuation section were subjected to an intense medical examination. In repeated examinations the character of the disorders remained as before. The authors noted a definite normalization of arterial pressure. The number of cases of hypotension was two times lower. The frequency of anemia decreased 4 times; the number of leukopenic conditions decreased. The authors conclude that the complex of symptoms described earlier (1961), related to the combined effect of a high-frequency field and X-ray radiation, with complete or partial removal of one of the factors, begins to even out and loses its characteristic traits.

Osipov, Yu. A., Ye. L. Kulikovskaya, and T. V. Kalyada. Conditions of The Radiation of Workers Constructing and Testing Electronic Instruments in a SHF Electromagnetic Field. Zhurnal Gigiyena i sanitariya, No. 2, 1962, pp. 100-102.

An important industrial process is the construction and testing of individual electronic instruments, conducted with the use of low-power (30-100 mW) klystron generators as SHF sources.

Depending on the radiation test equipment, either the worker's hands alone were irradiated or the hands and head, or the chest. /229

For protection, a special damper can be used which can be placed in the waveguide circuit of the transmitter.

Osipov, Yu. A., T. V. Kalyada, and Ye. L. Kulikovskaya. Observations on Some Functional Changes During Work in Persons Subjected to the Radiation of a Centimeter-wave Electromagnetic Field. Zhurnal gigiyena i sanitariya, No. 6, 1962, pp. 81-86.

Radiation, both general and local, of low-intensity centimeter waves (10 μ W/cm$^2$ and lower, as well as on the order of tens of μ W/cm$^2$) can cause certain transitory functional changes in personnel when they are at work, with respect to the CNS, the cardio-vascular system, and thermal regulation. The action of fields of such low intensities did not affect body temperature. Skin temperature of open surfaces increased markedly (up to 3° on the back of the hand, and 1.7° on the forehead) during the working day. The increase depends on radiation dosage and its periodicity. Optic chronaximetry data indicate an intensification of the inhibitory process during radiation with large SHF field doses and of the excitation process under the influence of lesser doses.

Pavlova, I. V., E. A. Drogichina, M. N. Sadchikova, and I. A. Gol'fon. Biochemical Changes Under the Chronic Effect of Superhigh Frequency Electromagnetic Fields. Collection: Gigiyena truda i biologicheskoye deystviye elektromagnitnykh voln radiochastot (Work Hygiene and the Biological Effect of Radio-frequency Electromagnetic Waves). Collection of Material of the Third All-union Symposium, 24-28 June 1968, Moscow, 1968, pp. 124-126. /230

Mild dysproteinemia, slight increase in total protein, cholesterol, a reduction of chlorides, and the presence of pathological sugar curves — which the authors observed in persons working with SHF radiation sources — are evidently related to disturbances in the regulatory function of the nervous system and to a change in hormone ratios, especially in the hypothalamus-pituitary-adrenal system. The authors also indicate pronounced disturbances of functional potentialities of the sympathetic-adrenal system.

Pradzhanadze, Sh. K. K mekhanizmy deystviya UBCh elektricheskovo polya na organizm (On the Mechanism of the Effect of a UHF Electric Field on the Organism). Collection of Works of the GosNII Kurortulogii i Fizioterapii (State Scientific Research Institute of Health Resorts and Physiotherapy). Georgian SSR, Tblisi, 1954, pp. 198-199.

Bioelectric changes develop when there are no indications of other reactions.

Pervyshin, V. Yu. On Changes in the Nerve Apparatus of the Heart Under the Influence of Superhigh Frequency Fields. Byull. eksper. biol. i med. 6, 1957, pp. 87-92.

The author established that under the effect of a SHF field, changes in the afferent neurons occur first, primarily at their ends. /231

A change in the receptors of the heart and individual cells of sensitive ganglia was also noted in radiation excluding thermal action.

Pretsovskiy, A. I., S. Ya. Trotsenko, and S. Ya. Guz. The Effect of a Superhigh-frequency Electromagnetic Field on the Course of Experimental Atherosclerosis. Patologicheskaya fiziologiya, 13, 2, 1969, pp. 64-66.

The authors showed the favorable effect in animals of a SHF field on the development and course of the atherosclerotic process. This was expressed by a lowered amount of lipides (also including cholesterol) in the blood, aorta and liver, less damage to the aorta by atherosclerotic deposits, a decrease and normalization of the propagation rate of pulsed waves.

Plekhanov, G. F. and V. V. Vedyushkina. Developing a Vascular Conditioned Reflex in Man to a Change in the Intensity of a High Frequency Electromagnetic Field. Zhurnal vyschey nervnoy deyatel'nosti, Vol. 16, Issue I, 1966, pp. 34-37.

The authors produced pronounced, conditioned-reflex vascular constriction. Having analyzed all possible ways of delivering the signal, the authors concluded that in these tests the stimulus was evidently the change in the intensity of the high-frequency electromagnetic field with constant and pulsed microwaves with an intensity of 10-15 $mW/cm^2$. Some tendency toward increased survival was noted in rats irradiated with constant microwaves, whereas pulsed microwaves worsened the effect from $\gamma$-radiation. /232

Promtova, T. N. The Effect of a Constant UHF Electric Field on Higher Nervous Activity of Dogs in Health and Pathology. Zhurnal vysshey nervnoy deyatel'nosti. 6, 1956, pp. 846-854.

Changes develop first in the CNS under the effect of UHF. The initial functional state of the animals is very important. In healthy dogs, an increase was first noted in food-conditioned reflexes with differentiation maintained — then there was a phase of sharp decrease in conditioned reflexes and retardation of differentiations. In dogs with disturbed higher nervous activity, the action of UHF worsened the pathological state of the cortex of the brain in the first phase, and normalized the higher nervous activity in the second phase.

Revutskiy, Ye. L. and F. S. Eidel'man. The Effect of Electromagnetic Fields in the Centimeter and Meter Ranges on the Amount of Biologically Active Substances in Human Blood. Fiziologicheskii zhurnal, AN Ukrainian SSR, 10, 3, 1964, pp. 379-393.

The authors discuss significant changes in the chemical content of blood which develop in the human organism under the influence of the brief action of electromagnetic fields in the 13.56 Mc range, which consist of a decrease in the amount of histamine in the blood.

Sadchikova, M. N. and A. A. Orlova. On the Clinical Treatment of the Chronic Effect of Electromagnetic Centimeter Waves. Zhurnal Gigiyena truda i profzabolevaniya, I, 1958, pp. 16-22. /233

With the periodic, brief action of very intense radiation, the biological effect of centimeter waves appears first of all in cardio-vascular and vegetative changes, depending on which vagotonic reactions predominate (hypotension, bradycardia, weak vascular reactions in functional tests, lengthening of intra-ventricle conductivity, reduced voltage of EKG waves, delayed dermographism). Under the constant motor effect of radiation with low intensities, the biological effect is expressed primarily in functional changes in the nervous system, characterized by general weakness, listlessness, increased irritability. The disorders are usually slight, and are reversed after even a brief interruption in work. The frequency of deviations in the nervous and cardio-vascular systems depended on the intensity and duration of radiation and the individual resistance of the organism.

Sevast'yanov, V. V. A Technique for Visually Recording the Results of the Action of a SHF Field on an Organism. Boyennomeditsinskiy zhurnal. I, 1969, pp. 54-55.

The author used visual coloration in an attempt to record visually the aftereffects of the influence of a SHF field on an organism. A 1% aqueous solution of Trypan blue was used as a dye.

Singatulina, R. G. The Effect of Ultrahigh-frequency Currents on Protein Fractions in Blood Serum. Byull. Eksperim. biologii i meditsiny, 1961, pp. 69-72. /234

It is noted that under the effect of a UHF electric field on rabbits, pronounced dysproteinemia develops, which is characterized by a decrease in the number of albumins and an increase in globulin fractions. Restoration of the original level in relation to protein fractions occurred only after 20 days.

Smurova, Ye. I., T. Z. Rogovaya, I. L. Yakub, and S. A. Troitskiy. The State of Health of Attendants of High (HF), Ultrahigh (UHF), and Superhigh (SHF) Frequency Generators in Physiotherapy Rooms. Kazanskiy meditsinskiy zhurnal, 2, 1966, pp. 82-84.

The study of the state of health of persons operating HF, UHF, and SHF generators in physiotherapy rooms revealed vegetative-vascular disturbances, an inclination toward anemia, leukopenia, thrombocytopenia, increased globulins and decreased albumin-globulin coefficient and a tendency toward lower cholinesterase activity.

Smurova, Ye. I. The State of Immunological Reactivity of an Organism under the Effect of Radio-frequency Electromagnetic Waves. Collection: Gigiyena truda i biologicheskoye deystviye elektromagnitnykh voln radiochastot (Work Hygiene and the Biological Effect of Radio-frequency Electromagnetic Waves). Moscow, 1968, pp. 145-146.

Animals were irradiated with SW, USW and MCW of nonthermal intensity. The data obtained indicate the effect of radiation on the phagocytic and bactericidal function of the blood. The changes have a two-phase course: activation changes to depression. /235

Smurova, Ye. I. Altered Phagocytic and Bactericidal Function of the Blood in Animals Under the Influence of Radio-Frequency Electromagnetic Fields. Gigiyena i sanitariya, 6, 1967, pp. 37-41.

Immunological reactivity is expressed in USW radiation first by activation of the phagocytic reaction, and an increase in the absorptive power of neutrophils. After 25 radiation sessions, a depression of the absorbing function and phagocytic reaction is observed. Comparing the effect of SW, USW, and MCW, the author showed that the most rapid changes occur in USW radiation.

Smurova, Ye. I. Hygienic Working Conditions of Medical Personnel Working in Physiotherapy Rooms with Radio-frequency Electromagnetic Field Sources. Zhurnal gigiyena truda i prof. zabolev., No. 1, 1966, pp. 17-20.

It is recommended that high-frequency equipment be screened with metal sheets, metal grids or special cotton fabric. Protection can be provided either by totally shielding the equipment or by using baffles and screens.

Smurova, Ye. I. and A. P. Volkova. The Effect of Radio-frequency Electromagnetic Fields on Phagocytes and the Course of Infectious Inflammation in Rats. Zhurnal Gigiyena i sanitariya, No. 9, 1967, pp. 107-110. /236

The effect of SW, USW and SHF on the phagocytic and bactericidal functions of the blood was studied in white rats. The change in phagocytic indices depends on the range and duration of the effect. The most pronounced depression of natural resistance was detected in the USW range.

Sokilov, V. V. and N. A. Chulina. Proliferations and Chromosome Damage in Bone Marrow Cells in Persons Who have Worked in a Superhigh-frequency Electromagnetic Field for a Long Time. Collection: Gigiyena truda i biologicheskoye deystviye elektromagnitnykh voln radiochastot (Work Hygiene and the Biological Effect of Radio-frequency Electromagnetic Waves). Collection of Material of the Third All-union Symposium, 24-28 June 1968. Moscow, 1968, pp. 147-148.

The chronic influence of SHF on the organism causes changes in the division process of bone marrow elements, expressed as a tendency toward an increased amount of mitoses and the presence of a small number of cells with chromosome damage. In all probability, this is the result of a change in the regeneration process in bone marrow, which tends to intensify. As a result, the total cellular content of bone marrow is maintained at a level close to normal.

Sokolov, V. V. and M. N. Arievich. On the Question of Changes in the Blood Under the Influence of SHF on the Organism. Collection: O biologicheskom vozdeystvii sverkhvysokikh chastot (On the Biological Effect of Superhigh Frequencies). Works of the Institute of Work Hygiene and Occupational Diseases, AMN SSSR, edited by Professor A. A. Letavat and Assistant Professor Z. V. Gordon, Candidate of Medical Sciences. /237
Issue 1, Moscow, 1960, pp. 43-46.

In response to the prolonged action of SHF with athermal intensity, there are slight changes in people, which are expressed in some instability of blood indices. Along with moderate leukopenia, a tendency is noted in a large percentage of cases toward an increased amount of leukocytes and reticulocytes.

Solovtseva, K. M. Vliyaniye induktotermii, UBCh, mikrovolnoy terapii na sostoyaniye svertyvayushchey i protivosvertyvayushchey sistemy krovi. (The Effect of Induction Heating, UHF, and Microwave Therapy on the Coagulation and Anti-coagulation Systems of the Blood). Material of the All-union Conference on Physiotherapy and Health Resort Treatment. 1965, p. 154.

The author points out definite changes in the coagulation and anti-coagulation system of the blood in persons under the effect of radio-frequency action.

Subbota, A. G. On the Effect of a Pulsed Superhigh-frequency (SHF) Electromagnetic Field on Higher Nervous Activity in Dogs. Byulleten' eksper. biol. i meditsiny, Vol. 46, No. 10, 1958, pp. 55-61.

The purpose of this work is to establish how the higher nervous activity of dogs changes in brief and chronic radiation with a SHF field of various intensity.

The direction of changes in intense radiation was, in the majority of cases, opposite to that which was observed after weak radiation. At PPM = 0.005 $W/cm^2$, increased salivation was observed at a positive conditioned /238
signal with relative stability of differentiations. The latent period of conditioned reflexes in the majority of cases is shortened when PPM = 0.1 $W/cm^2$. A positive conditioned reflex is almost always depressed, and differentiations are delayed. The latent period of conditioned reflexes is most often lengthened and phase effects are observed even more often than with a weak effect. Tests with brief irradiation of dogs showed that a weak SHF field usually intensifies the excitation processes. Active depression is evidently more resistant. Tests with repeated radiation indicated the possible adaptation of the cortex to the SHF field. Obviously there is also a cumulative effect of changes caused by radiation. Thus, under the effect of weak and intensive SHF fields, changes in higher nervous activity can occur in three ways: 1 - because of the direct penetration of electromagnetic waves into the brain, 2 - reflexively, because

of stimulation of receptor instruments, 3 - by a humoral-chemical route.

Tolgskaya, M. S., Z. V. Gordon, and Ye. A. Lobanova. Morphological Changes in Animals Under the Experimental Action of 10-centimeter Waves. Voprosy kurortologii, fizioterapii i lechebnoy fizkul'tury, I, 1959, pp. 21-24.

The effect of 10-centimeter waves of various intensity on the organism of animals is accompanied by a number of functional and organic changes. In brief intensive radiation (110 and 40 mW/cm$^2$) severe "clinical" symptoms /239
of overheating are observed, often leading to death. Morphologically predominant are severe vascular disorders in the form of plethora, edema, numerous hemorrhages of the brain and internal organs.

In the repeated, but less prolonged, action of large and medium doses, vascular disorders and degenerative changes in internal organs and the nervous system were less severe.

Under repeated radiations, the animals withstand the succeeding radiations better than the first. They continue to gain weight, and body temperature after irradiation is recovered quickly (30 min.), and overheating disappears.

Mesenchymal elements react moderately to the effect of small doses, more markedly to the repeated effect of medium and large doses, and not at all to the effect of lethal doses.

Tolgskaya, M. S. and I. A. Kitsovskaya. Morphologicheskiye issledovaniya nervnoy sistemy krys, chuvstvitel'nykh k zvukovomu razdrazhitelyu, pri vozdeystvii radiovoln. O biologiyeskom deystvii elektromagnitnykh poley radiochastot (Morphological Studies of the Nervous System of Rats Sensitive to Sound Stimulation Under the Influence of Radio Waves. On the Biological Effect of Radio-frequency Electromagnetic Fields), Moscow, 1968, p. 84.

The authors note that, under the effect of decimeter-range waves, along with the normal connections of pyramid neurons of the cerebral cortex with pronounced branching in the dendrites, there are isolated neurons or groups of neurons with obvious deformation of the apex dendrites. /240
Turbid and granular swellings of protoplasm are also noted in a large number of nerve cells. Changes were also detected in interoceptors of the myocardia and esophagous which were over-impregnated and thickened; evident swellings were observed in them. These changes were completely dependent on the duration of radiation.

Tolgskaya, M. S. and Z. V. Gordon. Change in the Neurosecretory Function of the Hypothalamus and the Neuro-pituitary Body During Chronic Irradiation with Centimeter Waves of Low Intensity. Collection: O biologicheskom deystvii elektromagnitnykh poley radiochastot (On the Biological Effect

of Radio-frequency Electromagnetic Fields). Works of the Laboratory of Radio-frequency Electromagnetic Fields, Institute of Work Hygiene and Occupational Diseases, AMN SSSR, Issue 3, Moscow, 1968, pp. 87-97.

The dynamics of changes in the neurosecretory function of the hypothalamus region are traced corresponding to phases of changes in vascular tone. The reversibility of the process is shown when radiation is terminated.

Tolgskaya, M. S. and Z. V. Gordon. Comparative Morphology of the Action of Microwaves of Various Ranges. Collection: O biologicheskom deystvii elektromagnitnykh poley radiochastot (On the Biological Effect of Radio-frequency Electromagnetic Fields). Works of the Laboratory of Radio-frequency Electromagnetic Fields, Institute of Work Hygiene and Occupational Diseases, AMN SSSR, Issue 2, Moscow, 1964, pp. 86-89.

The authors established that millimeter waves, absorbed in the surface layers of the skin, cause changes in internal organs by a nerve-reflex mechanism, whereas decimeter waves, penetrating more deeply, can have a direct effect on internal organs and the brain, leaving the skin intact. Centimeter waves, partially absorbed by the skin, can cause changes in it, as well as changes in more deeply located tissues. /241

Tolgskaya, M. S. and Z. V. Gordon. Changes in Receptor and Interoceptor Apparatus Under the Effect of SHF. Collection: O biologicheskom vozdeystvii sverkhvysokikh chastot. (On the Biological Effect of Super-high Frequencies). Works of the Institute of Work Hygiene and Occupational Diseases, AMN SSSR, Issue 1, Moscow, 1960, pp. 99-107.

Under the influence of low-intensity SHF-radiation, changes are detected in the receptor apparatus of the skin and internal organs, especially preterminal sections. Changes which develop in the organism depend not only on the direct effect of SHF on tissues and organs, but they can also be explained by the stimulation of receptors in various reflexogenic zones.

Tolgskaya, M. S. and P. P. Fukalova. Morphological Changes in Experimental Animals Under the Influence of Electromagnetic Fields with Short and Ultrashort Wave Ranges. Gigiyena truda i profzabolevaniya, No. 9, 1968, pp. 37-39.

Morphological changes in chronic irradiation by SW and USW of non-thermal intensities of 2250 V/m and 150 V/m, respectively, are characterized by slight vascular disorders and compensatory-proliferative processes, changes in receptor and interoceptor apparatus, and slight dystrophic changes in brain cells. In comparing the effect of USW and SW, the same biological action is recorded with less pronounced changes in the SW range. /242

Tolgskaya, M. S. and P. P. Fukalova. Morphological Changes in Experimental Animals Exposed to the Effect of Electromagnetic Fields in Radio-frequency

Ranges of 155 and 191 Mc. Collection: O biologicheskom deystvii EMP radiochastot (On the Biological Effect of Radio-frequency EMF). Works of the Institute of Work Hygiene and Occupational Diseases, AMN SSSR, Moscow, Issue 3, 1968, pp. 123-128.

A comparison of morphological changes at 191 and 155 Mc (at non-thermal radiation intensities of 20 and 10 V/m, 50 and 25 V/m, respectively) shows that the most pronounced changes are observed at 191 Mc, less at 155 Mc, and least of all at 69.7 Mc.

Tomashevskaya, L. A. and Ye. M. Makarenko. Vliyaniye elektricheskovo polya korotkovolnovovo diapazona na nekotorye biokhimicheskie protsessy v organizme. (The Effect of a Shortwave-electric Field on Certain Biochemical Processes in the Organism). Collection: Gigiyena naselennykh mest (Hygiene of Populated Areas). Kiev, 1967, pp. 38-39.

The authors note a decrease in cholinesterase activity in the blood in radiation with radio-frequency, electromagnetic waves. This can be considered an unfavorable sign, indicating a possible increase in the amount of acetylcholine participating in synaptic transmission of excitation in the nervous system. /243

Troyanskiy, M. P. On the Question of Irreversible Biological Effects caused by the Chronic Influence of SHF Fields. Gigiyena i sanitariya. 12, 1968, pp. 76-79. Bibliography.

Radiation at thermal (50 $mW/cm^2$) and non-thermal (10 $mW/cm^2$) intensities affects intra-uterine development, leads to changes in the function of higher centers of the central nervous system in prenatally irradiated animals at the age of 30-45 days. Radiating pregnant rats at an intensity of 10 $mW/cm^2$ accelerates post-natal development, and makes conditioned reflex indices worse in their offspring.

Animals pre-natally irradiated in a SHF field at an intensity of 50 $mW/cm^2$ and those derived from crossing irradiated males with non-irradiated females exhibited similar changes (anomaly development, deformities, peculiarities of higher nervous activity).

Troyanskiy, M. P. and R. I. Kruglikov. On the Question of the Effect of SHF Electromagnetic Waves on Offspring. Collection: Gigiyena truda i biologicheskoye deystviye elektromagnitnykh voln radiochastot. Moscow, 1968, pp. 157-158.

In the offspring of animals irradiated in SHF fields, besides abnormalities and developmental anomalies, disturbances in the functions of higher sections of the CNS were also observed in the form of delayed development and alteration of electro-defensive and motor-food conditioned reflexes, etc.

Troyanskiy, M. P., R. I. Kruglikov, and R. M. Kornilov. Some Results of Studies on the State of Health of Specialists Working with SHF Generators. Voyenno-meditsinskiy zhurnal, 7, 1967, p. 30. /244

In persons exposed to the weak chronic effect of microwaves, changes were detected in the EEG, mainly in the form of increased activity and synchronization of biopotentials; increased length of the latent period of waking up, listlessness, sometimes of a paradoxical character.

Tyagin, N. V. Aftereffects of a Superhigh-frequency Electromagnetic Field on Man. Vdyenno-meditsinskiy zhurnal, 2, 1965, p. 36.

EEG data are presented on examined persons which indicates that under the influence of weak, chronic microwave action, excitability and reactivity of the cerebral cortex is decreased.

Fisher, L. I. Materialy k izucheniyu fiziologicheskovo deystviya UVCh - terapii. (Data on the Study of the Physiological Effect of UHF-therapy). Collection: Voprosy fizioterapii i kurortologii (Problems of Physiotherapy and Health Resorts). Medgiz, 1959, pp. 46-50.

It is stressed that, when healthy persons are exposed to therapeutic doses of a UHF field, only a tendency toward lowered pressure is observed.

Fofanov, P. N. On the Clinical Observation of the Prolonged Effect of SHF Electromagnetic Radiation on Man. Sovremennaya meditsina 9, 1968, pp. 107-110. Bibliography.

Describing subjective disorders and objective data, the author points out /245 the vegetative-vascular character of changes in persons subjected to prolonged SHF action. In the majority of cases, changes in the functions of the nervous system were prominent. Also noteworthy is the increased emotional lability and reactivity of the examinees. The disorders have an unstable, functionally dynamic character. Moderate changes are noted in the activity of individual endocrine glands, which are evidently related to changes in the central nervous system. They indicate an increase in the function of the pituitary-adrenal system.

There are changes in the 17 ketosteroids and cathecholamines in urine, potassium and sodium in the blood and urine, the functional state of the thyroid gland, et al.

In turn, neuro-endocrine changes could cause a number of circulatory disorders which amount to moderate functional changes in hemodynamics and the electrical activity of the heart. Clinically these are expressed in vegetative-vascular disturbances with moderate dysfunctions of individual elements of the endocrine system.

Fukalova, P. P. The Effect of Short and Ultrashort Waves on Body Temperature and Survival of Experimental Animals. Collection: O biologicheskom deystvii EMP radiochastot (On the Biological Effect of Radio-frequency EMF). Works of the Institute of Work Hygiene and Occupational Diseases, AMN SSSR, Moscow, Issue 2, 1964, pp. 78-79.

A field intensity of 2500 V/m for SW (14.88 Mc) and 200 V/m for USW (69.7 Mc) is the threshold value, below which no thermal effect is observed. At the same intensity of 5000 V/m — in the USW range for 5 minutes, 100% of the animals died; in the SW range, lasting 1 hr 40 min., 80% of the animals die. /246

Fukalova, P. P. The Effect of USW Electromagnetic Fields (155, 191 Mc) on Survival and Thermal Reaction of Experimental Animals. Collection: O biologicheskom deystvii EMF radiochastot. (On the Biological Effect of Radio-frequency EMF). Works of the Institute of Work Hygiene and Occupational Diseases, AMN SSSR, Moscow, Issue 3, 1968, pp. 101-103.

The increase of thermal action with increased frequency of EM fluctuations is discussed.

Body temperature in animals increases at an intensity of 200 V/m in the 69.8 Mc range, 70 V/m in the 155 Mc range, and 35 V/m in the 191 Mc range.

Fukalova, P. P. The Effect of EMF in the USW Range on the Level of Blood Pressure in Experimental Animals. Collection: O biologicheskom deystvii EMP radiochasto (On the Biological Effect of Radio-frequency EMF). Works of the Institute of Work Hygiene and Occupational Diseases, ANM SSSR, Moscow, Issue 3, 1968, pp. 104-106.

Chronic radiation of animals with USW electromagnetic fields is accompanied by a two-phase reaction of blood pressure: at first an increase, and then a decrease in blood pressure level. The increasing phase in the 155 and 191 Mc ranges was more prolonged than in the 69.7 Mc range. When radiation is continued, a persistant decrease in pressure is observed in all ranges. /247

Fukalova, P. P. Hygienic Evaluation of Working Conditions in Thermal Treatment of Dielectrics in High-frequency Equipment. Gigiyena truda i professional'nye zabolevaniya, No. 3, 1963, pp. 3-8.

The thermal treatment of dielectrics (welding polyvinylchloride plasticized resins and patching wooden products in HF equipment) field intensity can be lowered by shielding the energy sources of the capacitor and feeder lines.

Fukalova, P. P. Characteristics of a Work and Rest Regime in Radio Stations Constantly Operating Under the Influence of Electromagnetic Radiation. Gigiyena truda i profzabolevaniya, No. 9, 1969, pp. 15-19.

Working under the effect of electromagnetic fields in radio stations is aggravated by a non-efficient regime of work and rest, leading to changes in certain physiological reactions and the development of fatigue. This was the basis, along with recommendations for protective measures against the effect of electromagnetic fields, for changes in the work and rest regime of on-duty personnel.

Fukalova, P. P. The Effectiveness of Protective Measures Against the Influence of Electromagnetic Fields of Short and Ultra-short Waves (SW and USW) on Radio- and Television Stations. Gigiyena i sanitariya, No. 5, 1966, pp. 112-114. /248

Electromagnetic fields intensity can be decreased either by shielding individual radiation sources in the radio transmitting equipment, or by remote control of the transmitters.

Fukalova, P. P. Hygienic Characteristics of Working Conditions with SW and USW Sources in Radio and Television Stations. Collection: O biologicheskom deystvii EMP radiochastot. (On the Biological Effect of Radio-frequency EMF). Works of the Institute of Work Hygiene and Occupational Diseases, AMN SSSR, Moscow, Issue 2, 1964, pp. 158-163.

Sources of high-frequency fields in radio stations can be poorly shielded, high-frequency elements in transmitter units, power equipment and dividing filters, unshielded transmission lines, and emitting antenna systems. Field intensity can be decreased by shielding radiation sources or by operating the transmitters by remote control.

Fukalova, P. P. Hygienic Evaluation of Working Conditions in Television Radio Stations Using New Transmitter Systems. Collection: O biologicheskom deystvii elektromagnitnykh poley radiochastot (On the Biological Effect of Radio-frequency Electromagnetic Fields). Works of the Laboratory of Radio-frequency EMF, Institute of Work Hygiene and Occupational Diseases, AMN SSSR, Issue 3, Moscow, 1968, p. 26-29.

Research data are presented which show that new transmitter systems and additional shielding of old transmitters, their efficient placement, and organizing centralized transmitter control provide effective protection from the effect of EMF, and create normal working conditions for the personnel on duty at the control panel. /249

Fukalova, P. P. The Sensitivity of Olfactory and Optic Analyzers in Persons Exposed to the Effect of Constantly-generated SW and USW. Collection: O biologicheskom deystvii EMF radiochastot. (On the Biological Effect of Radio-frequency EMF). Works of the Institute of Work Hygiene and Occupational Diseases, AMN SSSR, Moscow, Issue 2, 1964, pp. 144-148.

Workers under short- and ultrashort wave conditions revealed increased thresholds of olfactory sensitivity and a change in the time of dark adaptation in proportion to the length of time on the job.

Fukalova, P. P. and M. S. Tolgskaya. A Study of Working Conditions and the Biological Action of Electromagnetic Fields of the 155 and 191 Mc Range. Collection: Gigiyena truda i biolog. deystv. elektromagnitnykh voln radiochastot (Work Hygiene and the Biological Effect of Radio-frequency Electromagnetic Waves). Collection of Material from the III All-union Symposium. Moscow, 1968, pp. 163-164.

A hygienic evaluation is made of working conditions using new transmitter systems which operate at frequencies of 170-212 Mc, and data on the experimental study of these frequencies are given, indicating their great /250
effectiveness in comparison with 69.7 Mc.

Fukalova, P. P., M. S. Tolgskaya, S. V. Nikogosyan, M. A. Kitsovskaya, and I. N. Zenina. Materialy issledovaniy k normirovaniyu elektromagnitnykh poley diapazona korotikh i ul'trakorotkikh voln. (Research data on Setting Up Standards for Electromagnetic Fields in the Short- and Ultrashort Wave Range). Gigiyena truda i professional'nye zabolevaniya, No. 7, 1966, p. 5.

SW and USW waves cause changes in a number of indices characterizing the functional state of the cardio-vascular and nervous systems. The degree to which the changes are expressed depends on wave range, intensity and length of radiation. The establishment of maximum permissible intensities in SW and USW ranges is based on data from clinical, physiological, biochemical and morphological research. MPL in the USW range is recommended at 5 V/m and in the SW range — 20 V/m.

Kholodov, Yu. A. Vliyaniye elektromagnitnovo i magnitnovo poley na tsentral'nuyu nervnuyu sistemy (The Effect of Electromagnetic and Magnetic Fields on the Central Nervous System). "Nauka" Press, Moscow, 1966.

Damage to any distant analyzer lowers the stability of the reaction to a UHF field and increases the latent period, but the presence of an EEG reaction to a UHF field in a rabbit after distant analyzers were damaged is apparent. The reaction of the organism to a UHF field is determined by the reflex action and direct action on the peripheral nervous system (PNS), which is verified by the data of other authors.

Kholodov, Yu. A. and Z. A. Yanson. Ob izmenenii elektricheskoy aktivnosti /251
kory goloynovo mozga krolika pod vozdeystviyem elektromagnitnovo polya UVCh (On Changes in the Electrical Activity of the Cerebral Cortex of a Rabbit Under the Effect of a UHF Electromagnetic field). Report I, Byull. eksper. biol. i med., 55, II, 1962, pp. 8-12.

To show the possibility of the direct action of the UHF field on the nervous system, the authors, using the electrophysiological method, showed a change in amplitude (increase) and frequency (decrease) of biocurrents of the cerebral cortex.

These changes developed at a time when there were no other reactions according to other indices. (Bychkov 1957, Drogichina, Sadchikova, Ginzburg, 1962; Pardzhanadze 1964, Kholodov 1966).

Kholodov, Yu. A. and P. N. Zenina. The Effect of Caffeine on the EEG Reaction Under the Influence of a SHF, Pulsed Field on the Intact and Isolated Brain of a Rabbit. Collection: O biologicheskom deystvii elektromagnitnykh poley radiochastot (On the Biological Effect of Radio-frequency Electromagnetic Fields). Works of the Laboratory of Radio-frequency Electromagnetic Fields, Institute of Work Hygiene and Occupational Diseases, AMN SSSR, Issue 2, Moscow, 1964, p. 33.

It is shown that the injection of caffeine also increases the sensitivity of the intact and isolated brain of a rabbit to a SHF pulse field.

Chizhenkova, R. A. Background and Induced Activity of Neurons of the Optical Cortex of a Rabbit after the Action of a SHF Field. Zhurnal vysshey nervnoy deyatel'nosti, 19, 3, 1969, pp. 495-501. /252

A SHF electromagnetic field with PPM = 40 $mW/cm^2$ after one-minute action on the head of a rabbit can cause changes in the background activity of neurons in the optical cortex of the brain. The SHF field facilitates responses of the neurons to a flash of light.

Judging from morphological data, glial elements could be more sensitive to UHF than the neurons.

Chirkov, M. M. The Effect of the Energy of a Radio-frequency Electromagnetic Field on Interoceptive Exchange Reflexes. Collection: Materialy nauchoy konferentsii po probleme Fiziologiya i patologiya kortikovistseral'nykh vzaimootnoxheniy i funktsional'nykh sistem organizmov. (Material of the Scientific Conference on the Problem "Physiology and Pathology of Cortical-visceral Interrelations and Functional Systems of Organisms"). I, II, Ivanovo, 1965, pp. 469-472.

The author indicates that the UHF field is one of the factors in the environment able to change the intensity of exchange processes and the activity of the apparatus regulating metabolism in the organism.

In radiating the head of rabbits (9.5 Mc), a decrease was observed in the activity of oxidizing enzymes in the blood (catalase, peroxidase). In repeated radiations, the activity of the blood was altered; the activity of catalase and peroxidase increased. The author did not observe the changes immediately, but 5 - 150 minutes after the effect was terminated. /253

Chukhlovin, B. A. The Formulation of Specific Antibodies Under the Effect of SHF-radiation on the Organism. Collection: Gigiyena truda i biologicheskoye deystviye elektromagnitnykh voln radiochastot (Work Hygiene and The Biological Effect of Radio-frequency Electromagnetic Waves). Moscow, 1968, pp. 172-173.

It was established that general radiation of 5-6 months old rabbits at a PPM of 50 $mW/cm^2$, both before and after vaccination, decreased the titer of specific antibodies. An intensity of 10 $mW/cm^2$ stimulates antibody-formation, which evidently depletes reserve resources of the organism for synthesizing agglutinins, since a repeated cycle of radiation 2-3 months after immunization increases the titer of antibodies only in previously non-irradiated animals.

Shemyakov, S. I. Some Data on Medical Observations in Electronic Stations. Voyenno-meditsinskiy zhurnal. Moscow, 5, 1955, pp. 79-83.

Sexual disorders were observed — decreased sexual ability in men, and menstrual disorders in women who worked with USW sources.

Shlefer, T. P. and M. I. Yakovleva. The Effect of Superhigh-frequency Electromagnetic Fields on the Pulsed Activity of Neurons in the Cerebral Cortex. Fiziologicheskiy zhurnal SSSR, 55, I, 1969, pp. 16-21.

The functional state of individual neurons in the cortex under the effect /254
of a SHF field was shown by the authors in studies of the pulsed activity of neurons in the cerebral cortex. They detected a decrease in the frequency of the spontaneous background of bioelectrical activity of neurons in the somatosensory zone of the cortex, a decrease in the number of cortical cells, which react to the effect of stimuli, and a number of other indices which indicate that the SHF-field lowers the excitability and functional mobility of cells in the cerebral cortex of rats.

Shtemler, V. M. The Effect of Radio-frequency Electromagnetic Field Radiation on the Activity of Catalase and Cholinesterase Enzymes. Collection: Gigiyena truda i biologicheskoye deystviye elektromagnitnykh voln radiochastot (Work Hygiene and the Biological Effect of Radio-frequency Electromagnetic Waves). Collection of Material of the Third All-union Symposium, 24-28 June 1968, pp. 175-177.

In an experiment in vitro, an attempt was made to detect the direct effect of radiation with 10 cm waves on molecules of the catalase and cholinesterase protein-enzymes. The studies showed that the possibility of a direct effect of radiation on enzyme molecules is unlikely.

Shcheglova, A. V. On Qualitative Changes in Erythrocytes in Persons Working Under the Combined Effect of Occupational Factors ($\gamma$-radiation, High-frequency Currents, Lead). Problemy hematologii i perelivaniya

krovi, Vol. 7, No. 6, 1962, pp. 35-37. /255

The simultaneous effect or roentgen rays and high frequency currents caused more severe change in the osmotic resistance of erythrocytes than each of these factors individually. Under the simultaneous effect of γ-radiation and lead, changes in the resistance of erythrocytes had the same character as under the effect of lead alone.

On the basis of this work, it can be said that under the simultaneous action of two occupational factors, qualitative changes in erythrocytes are encountered more often than under the effect of one factor. The qualitative changes in erythrocytes were not specific for any certain factor, but they precede quantitative changes and therefore should be considered in blood analysis.

Evenshteyn, Z. M., A. F. Stakh, and Yu. V. Leybin. On the Sterilization of Injection Solutions in a SHF Field. Voyenno-med. zhurn. No. 6, 1969, pp. 79-80.

1. UHF, HF, and SHF — application.

2. Infusions and injections.

The bactericidal effect of the SHF field is well-known (culinary preparation and preserving food products — A. N. Vyshelestskiy, 1963, Semdomskaya, D. V., 1956) even at non-thermal intensities. The author showed that sterilizing injection solutions in a SHF field can be more effective in comparison with existing methods. /256

Yakovleva, M. I. The Effect of Superhigh Frequency Electromagnetic Fields on Conditioned-reflex Regulation of Cardiac Activity and Respiration. Zhurnal vyschey nervoy deyatel'nosti. V. 18, Issue 3, 1968, pp. 418-423.

The single application of a SHF field with PPM = 5mW/cm$^2$ with a wavelength of 12.6 cm does not cause changes in cardiac and respiratory reflexes in rabbits. A SHF field with PPM = 14-26 mW/cm$^2$, applied once, causes an increase in the stability of cardiac and respiratory, conditioned reflexes. The prolonged 1-3 month action of SHF fields with PPM = 5 mW/cm$^2$ increases the level of cardiac, conditioned reflexes or causes no change. In only one rabbit was a decrease in the stability of conditioned reflexes noticed; this was later restored against a background of continued radiations.

The level of respiratory, conditioned revlexes under the influence of a SHF field with PPM = 5 mW/cm$^2$ and more (to 100 mW/cm$^2$) was essentially undisturbed in the majority of rabbits. The frequency of cardiac and respiratory, conditioned reflexes was increased faster under the effect of the prolonged application of SHF fields than in intact rabbits.

Yakovleva, M. I. Studies of the Effective Pulsations in Post-ganglion Sympathetic Fibers Under the Influence of a Superhigh-frequency Electromagnetic Field. Byull. eksp. biol., 66, 9, 1968, pp. 9-11. Bibliography.

The background bioelectric activity recorded in cats in efferent fibers /257
of renal, splenic and lower mesenteric nerves under the single application of a SHF field with PPM = 30 mW/cm$^2$ increases in 50% of the cases, but at greater PPM in all cases.

Yakovleva, M. I., T. P. Shlyafer, and I. P. Tsvetkova. On the Question of Conditioned Cardiac Reflexes, the Functional and Morphological State of Cortical Neurons Under the Effect of Superhigh-frequency Electromagnetic Fields. Zhurn. vyschey nervoy deyatel'nosti. Vol. 18, Issue 6, 1968, pp. 973-978.

Single and repeated interactions of SHF fields with PPM = 5-15 mW/cm$^2$ weaken the excitation process and decrease the functional mobility of cells in the cerebral cortex of rats. Most often noted are edematic changes in nerve cells throughout the entire cross-section of the cortex. The greatest number of altered cells is encountered in the repeated application of a SHF field with PPM = 15 mW/cm$^2$.

These changes in the function of neuron structure in the cerebral cortex are noted when damage to conditioned-reflex regulation of cardiac activity in rats is absent.

Yashina, L. N., I. S. Ostrovskaya, N. N. Goncharova, and V. B. Karamyshev. Morphological Changes in the Internal Organs of Experimental Animals Under the Effect of USW, Radio-frequency Electromagnetic Waves. Collection: Gigiyena truda i biologicheskoye deystviye elektromagnitnhkh voln /258
radiochastot (Work Hygiene and the Biological Effect of Radio-frequency Electromagnetic Waves). Collection of Material of the Third All-union Symposium, 24-28 June 1968, Moscow, 1968, pp. 180-181.

As a result of a morphological study, the uniformity of tissue reactions was established (hemodynamic disorders, dystrophic changes in parenchymatous organs and the CNS). The authors also observed a gradual proliferative reaction of cells in connective tissue with the formation of lymphohistiocytic nodules which can be considered as the morphological reflection of one of the compensation and adaptation mechanisms.

Yatsenko, M. I. The Participation of the Sympathetic and Parasympathetic Nervous System in the Action of Microwaves on Knee Joint Bending Ability. Voprosy kurortologii, 2, 1969, pp. 158-161. Bibliography.

Vagosympathetic innervation participates in the regulation of absorption processes by the synovial membrane of the knee joint under the effect of microwaves.

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